USAAEFA PROJECT NO. 79-06

PRELIMINARY AIRWORTHINESS EVALUATION (PAE 1) OF THE YCH-47D HELICOPTER

FINAL REPORT

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Climb Performance
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YCH-47D Helicopter
Level Flight Performance
Handling Qualities

20. ABSTRACT (*Continue on reverse side if necessary and identify by block number*)

The Preliminary Airworthiness Evaluation of the YCH-47D helicopter was conducted between 11 September and 6 December 1979. Seventeen flights were required for a total of 41.4 hours, of which 32.8 hours were productive. Testing was conducted at the Boeing Flight Test Facility at Wilmington, Delaware. The YCH-47D exhibits improved lift capability at a hover (both in and out of ground effect) when compared to the CH-47C with fiberglass rotor blades and T55-L-712 engines. Higher airspeeds are also possible at high gross weights. The AFCS was found to be an enhancing characteristic. Twenty shortcomings and one deficiency were also documented during the test. The deficiency of delay in power steering activation should be corrected prior to operational deployment.

Power

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The noise level in the cockpit and cabin showed no apparent improvement over previous models and was of sufficient magnitude to induce temporary hearing loss without adequate protection. The vibration levels became excessive above 145 KIAS, increasing to unacceptable prior to V_H, with 6 per rev vibrations being predominent.

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1. The purpose of this letter is to establish the Directorate for Development and Qualification position on the subject report. PAE 1 was the first Government evaluation of the YCH-47D following contractor development testing. The evaluation was conducted to determine the development status and verify a flight envelope for operational testing. It is important to note that the intent of the Modernized Chinook program was to improve reliability and maintainability characteristics of the CH-47 helicopter. Consequently, numerous shortcomings inherent to the CH-47 helicopters were not corrected and hence still exist. These shortcomings are minor compared to the overall improvements resulting from the Modernized Chinook effort and do not significantly impact the operational capability of the CH-47D.

2. This Directorate is not in complete agreement with the report findings, recommendations and conclusions. The following comments are provided relative to the preceding as well as comments on corrective actions and are directed to the report paragraphs as indicated.

a. Paragraph 78. The problem associated with the power steering was determined to be a vendor design problem which was corrected and verified as acceptable during subsequent testing. The correction will be incorporated in the production configuration.

b. Paragraph 79a. The lighting shortcomings peculiar to the YCH-47D were corrected, however, those common to the CH-47A/B/C still exist.

c. Paragraph 79b. While the vibration levels of the YCH-47D failed to meet the requirements of MIL-M-8501A, they occur at an airspeed greater than cruise. The CH-47C also has similar vibration characteristics. Corrective action would require a significant design change to the CH-47D which is cost prohibitive at this time.

d. Paragraph 79c. While the noise levels are high in the YCH-47D and still considered a shortcoming, they are lower than those measured in the CH-47 under similar conditions and consequently, are an improvement.

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e. Paragraph 79d. The poor power management characteristics of the YCH-47D with the T55-L-712 engines are similar to those of the CH-47C with the T55-L-712 engines.

f. Paragraph 79e. The poor visibility of the fore and aft hooks during tandem hook operations is not correctible at this time but is acceptable.

g. Paragraph 79f. The high ambient noises of the YCH-47D results in the requirement for crew members to wear ear plugs. This situation results in insufficient volume of the interphone set. However, the volume of the interphone set cannot be increased further due to limitations established by the Surgeon General of the Army.

h. Paragraph 79g. The lack of a mute capability in the intercom set is an existing problem on the GFE, C-6533 intercom set, correction of which was not a part of the Modernized Chinook program.

i. Paragraph 79h. The high lateral breakout force on the cyclic beep trim button was reduced and the design change will be included in the production configuration.

j. Paragraph 79i. The lack of protection for the AC bus tie relay circuit breakers was corrected by incorporating a protective device design change which will be included in the production configuration.

k. Paragraph 79j. The unreliability of the radar altimeter during tandem external load operations occurred when carrying the M-198 howitzer. The radar tends to lock on the gun barrel. A note to this effect will be included in the Operator's Manual.

l. Paragraph 79k. The poor location of the emergency power lights was corrected by going to one light adjacent to the pilot's torque meter. The light will illuminate when either engine uses emergency power.

m. Paragraph 79l. The location of the engine starter lights will remain the same. While the report comments on the location being poor, it is not unacceptable. Since the YCH-47D requires a pilot and copilot, one of the crewmembers could monitor the lights. Relocation of the lights to the instrument panel requires a design change to an edge lit panel which the Modernized Chinook PMO determined would not be cost effective.

n. Paragraph 79m. The brake/steer and ramp isolation switches were incorporated to provide a capability to isolate the utility hydraulics system in the event of battle damage. This was an aircraft survivability equipment (ASE) requirement.

o. Paragraph 79n. The utility and flight control hydraulic pressure gages were replaced with caution lights on the instrument panel. The gages were relocated to the maintenance panel. This allowed conserving space on the instrument panel, yet still providing the pilot with an indication of a hydraulic system failure. The gages are still available and can be monitored by the crew chief. This action is not considered a shortcoming.

p. Paragraph 79o. The susceptibility of the longitudinal stick position indicator to impact damage will be reduced by changing the glass plate to plastic. This design change will be included in the production configuration.

q. Paragraph 79p. The location of the maintenance panel will not be changed. However, the panel will be hinged so that it can be monitored more effectively. This design change will be included in the production configuration.

r. Paragraph 79q. The problem of collective creep at high power settings is being investigated. It is anticipated a design change to the thrust control system will be incorporated on the first production CH-47D.

s. Paragraph 79r. The tendency of the longitudinal speed trims and dash to program to the fly position at light gross weights was corrected by redesigning the landing gear squat switch. The squat switch was not reliably actuated upon touchdown at light gross weights thereby causing the speed trims to program to the fly position with the helicopter light on the wheels. The design change will be incorporated in the production configuration.

t. Paragraph 79s. The pitch inputs to the AFCS by manually adjusting the VGI occurs when a rapid adjustment is made. No design change will be made, however, a note will be incorporated in the Operator's Manual.

u. Paragraph 79t. The amber APU on light on the caution panel is appropriately colored. The APU is not flight rated, it is only operated on the ground for engine starts and shutdown. Consequently, if the APU is running when the helicopter is airborne, a caution indication is appropriate.

v. Paragraph 80a. The longitudinal cyclic limit force failed to meet the requirements of MIL-M-8501A. However, these requirements may be waived as tests showed the force characteristics to be satisfactory.

w. Paragraph 80b. The mechanical characteristics of the thrust control failed to meet the requirements of MIL-H-8501A and were also unsatisfactory. Action is being taken to correct these characteristics (see paragraph 2r above).

x. Paragraph 81. The deficiency related to a lack of capability to immediately switch from the locked to the steer mode on the aft gear was corrected (see paragraph 2a above).

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y. Paragraph 83. The warning note in this paragraph is not now applicable. The extreme inputs resulting from simulated dual AFCS failures was corrected and tested as satisfactory following PAE 1 of the YCH-47D helicopter. The design change will be incorporated in the production configuration.

z. Paragraph 84. A note will be incorporated in the Operator's Manual advising that the altitude hold feature of the AFCS does not provide engine or transmission protection and may produce overtorques or overtemps.

3. The overall improvements of the YCH-47D over the CH-47A/B/C helicopters are significant and provide the user with an increased capability both in performance and handling qualities. Additionally, reliability and maintainability should be greatly improved.

FOR THE COMMANDER:

CHARLES C. CRAWFORD, JR.
Director of Development
and Qualification

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INTRODUCTION

BACKGROUND

1. The US Army has contracted with Boeing Vertol Company (BV) to convert three models of the CH-47 medium lift helicopter to the CH-47D configuration. This program incorporates improvements in the areas of flight safety, reliability and maintainability, vulnerability, and survivability.

2. Modernized components which have been incorporated include fiberglass rotor blades (FRB), new/uprated transmissions, and improved external cargo suspension, hydraulic, electrical, and flight control/stability augmentation systems. The engines have been replaced with the more powerful T55-L-712 models.

3. The US Army Aviation Research and Development Command (AVRADCOM) directed the US Army Aviation Engineering Flight Activity (USAAEFA) to plan and conduct a Preliminary Airworthiness Evaluation (PAE) of the YCH-47D helicopter (ref 1, app A).

TEST OBJECTIVES

4. The test objectives were:

a. Conduct sufficient performance testing to determine compliance with the contractual guarantees per BV Document 145-PJ-7103 (ref 2, app A) for the mission I and mission III profiles and the out of ground effect (OGE) hover capability.

b. Conduct limited performance testing at various weights and rotor speeds to obtain data for inclusion in the operator's manual.

c. Determine maximum airspeed (V_H) for sea level standard conditions at 33,000 pounds gross weight (guaranteed capability).

d. Determine one engine inoperative (OEI) service ceiling for standard atmospheric conditions using emergency power (guaranteed capability).

e. Conduct limited handling qualities and vibration testing to evaluate compliance with the requirements of MIL-H-8501A (ref 3, app A) as amended by BV Document 145-PJ-7103.

f. Determine noise levels to evaluate compliance with the requirements of BV Document 145-PJ-7103.

DESCRIPTION

5. The YCH-47D is a twin-engine, turbine-powered, tandem rotor cargo helicopter manufactured by the Boeing Vertol Company, a Division of the Boeing Company (Boeing Vertol). Helicopter S/N 76-18538 (BV003) was used for the acoustics tests, and S/N 76-18479 (BV002) was used for all other tests. A detailed description is contained in the operator's manual (ref 4, app A) and the Prime Item Development Specification (ref 2, app A). A brief description of the the test aircraft is contained in appendix B.

TEST SCOPE

6. The PAE was conducted in 17 flights for a total of 41.4 hours, of which 32.8 were productive. Testing was conducted in the vicinity of the Greater Wilmington Airport, Wilmington, Delaware (80-foot elevation). Testing was initiated on 11 September 1979 and delayed after two flights due to an aircraft accident. Testing was resumed on 16 November 1979 and completed on 6 December 1979. The contractor installed, calibrated, and maintained the instrumentation and performed all maintenance on the test aircraft.

7. Performance testing was conducted over a range of weights and rotor speeds as shown in table 1. Handling qualities were evaluated against the requirements of MIL-H-8501A as modified by BV Document 145-PJ-7103 under two target test weights of 33,000 and 50,000 pounds, and the conditions shown in table 2.

8. The flight restrictions and operating limitations applicable to the PAE are contained in the operator's manual and the airworthiness release (ref 5, app A).

TEST METHODOLOGY

9. The test techniques utilized were standard engineering flight test techniques (refs 6 and 7, app A) and are briefly described in appendix D. Qualitative ratings of the handling qualities were based on the Handling Qualities Rating Scale (HQRS) contained in appendix D. Vibration levels were qualitatively evaluated using the Vibration Rating Scale (VRS) contained in appendix D.

10. Data were recorded by hand, on magnetic tape onboard the aircraft, and via telemetry to the BV Simulation and Test Analysis in Real Time Laboratory (STARLAB) located at Wilmington, Delaware, and Philadelphia, Pennsylvania. A detailed listing of the test parameters is contained in appendix C.

Table 1. Performance Test Conditions

Test	Thrust Coefficient (C_T)	Referred Gross Weight w/δ (LB)	Engine Start Gross Weight (LB)	Center of Gravity Location[1] (FS)	Referred Rotor Speed $N/\sqrt{\theta}$ (rpm)	Pressure Altitude[1] (Ft)	Outside Air Temperature[1] (°C)	Trim Calibrated Airspeed (KTS)
Hover: 10' IGE			32526	326.4		-30	-4	0
150' OGE			32397	325.5		30	16	0
Level Flight	0.00500	33579	32519	326.4	225	2500	11	38-155
		36630	32577	326.2	235	4560	7	49-158
		39814	32735	327.0	245	6380	2	36-141
	0.00600	40295	32577	326.2	225	9200	6	55-139
	0.00700	47011	44236	335.5	225	2200	12	40-155
	0.00784	52625	44236	335.5	225	7000	4	48-141
		57407	44200	335.5	235	9200	2	41-131
		59876	51955	330.3	240	6700	2	40-137
		62376	51986	330.3	245	7100	1	37-137
	0.00900	60443	44200	335.5	225	9300	2	38-119
		65934	51955	330.3	235	7900	-1	47-121
		71664	51986	330.3	245	9540	-4	37-112
Level flight with Sling Load (XM 198 Howitzer)	0.00700	47011	46713	325.7	225	2360	6	63-138
	0.00784	52625			225	4430	4	55-133

Table 2. Handling Qualities and Other Test Conditions

Test	Gross Weight[1] (lb)	Center of Gravity Location[1] (FS)	Density Altitude[1] (ft)	Outside Air Temperature[1] (°C)	Trim Calibrated Airspeed (KTS)	Rotor Speed (rpm)
Control positions	30,580 42,760	331.1 327.5	2480 9860	12 2.4	0 to 150	223 220
Static stability	30,000 47,000	330.0 331.7	5000	8 7	66,67,118,120 64,119,124	225
Maneuvering stability	29,600	331.2	5000	9	121	225
Dynamic stability	30,360	329.9	5000	8	60, 121	225
Controllability:						
Hover	32,560 51,660	328.9 330.3	-1000 -700	6 9	0	225
Level flight	31,900 49,880	329.2 330.8	5000	7 -1.5	65 and 121	225
Mechanical characteristics	Test conducted on ground with GPU supplying pressure to #2 system					
Vibrations	39,280	324.0	2000	10	40 - 158	225
Acoustics	31,000	328.2	-	-	140, 155	225

[1] Average values

RESULTS AND DISCUSSION

GENERAL

11. Performance, handling qualities, acoustics, and vibration testing of the YCH-47D was conducted at the BV flight test facility at the Greater Wilmington Airport, Wilmington, Delaware. The YCH-47D exhibits improved lift capability at a hover (both in and out of ground effect) when compared to the CH-47C equipped with FRB and T55-L-712 engines. Higher airspeeds are also possible at high gross weights. In general, the handling qualities meet the requirements of the detail specification, and the addition of the Advanced Flight Control System (AFCS) was found to greatly enhance the operational capability of the aircraft. The noise level within the cabin and cockpit showed no apparent improvement over previous models and proved to be of sufficient magnitude to induce temporary hearing loss without proper hearing protection. The vibration levels were acceptable up to 145 knots indicated airspeed (KIAS) with 6 per rev vibration being predominent. At airspeeds above 145 KIAS, the vibration levels are excessive.

12. Twenty shortcomings and one deficiency were documented during this test. After correction of the deficiency in power steering activation the YCH-47D will be acceptable.

PERFORMANCE

General

13. Tests were conducted to evaluate hover, level flight, and climb performance under the conditions listed in table 1. The results are presented in figures 1 through 11, appendix E, with guarantee compliance summarized in table 3. Standard flight test techniques and data reduction methods, as outlined in appendix D and reference 6 of appendix A, were utilized during these tests. Comparison data for the CH-47C with FRB and T55-L-712 engines were obtained from USAAEFA Report No. 77-31 (ref 8, app A).

14. The YCH-47D exhibits improved lift capability in both hover and level flight when compared to the CH-47C and the maximum level flight airspeed (V_H) is increased at high gross weights (above 45,000 lbs). However, the vibration level was found to be excessive above 145 KIAS increasing to unacceptable at V_H under all conditions tested.

Hover Performance

15. Hover performance of the YCH-47D was evaluated using the tethered hover method. The test results are presented as figures 1 and 2 for an in ground effect (IGE) hover, at an aft wheel height of 10 feet, and for an OGE hover at an aft wheel height of 150 feet.

16. Figures A and B compare the YCH-47D data with results obtained from the CH-47C equipped with FRB and T55-L-712 engines. The YCH-47D data show a slight increase in power required when compared to the CH-47C with FRB at equivalent referred gross weights. This increase averages approximately 150 SHP IGE and 95 SHP OGE and may be attributed partially to increased power requirements

Table 3. Performance Guarantee Compliance

Condition	Guarantee	Actual	Percent Guarantee Exceeded
Mission I (external load)	15,000 lb	16,529 lb	10%
Mission III (internal load)	13,000 lb	15,414 lb	18%
Max level flight speed (V_H)[1]	155 KTAS	157.5 KTAS	1.6%
One engine inoperative service ceiling[2]	10,000 ft	13,100 ft	31%
OGE hover capability[3]	50,000 lb	54,650 lb	9.3%

[1] Maximum continuous rated power on both engines
[2] Emergency power on operable engine
[3] Maximum power on both engines

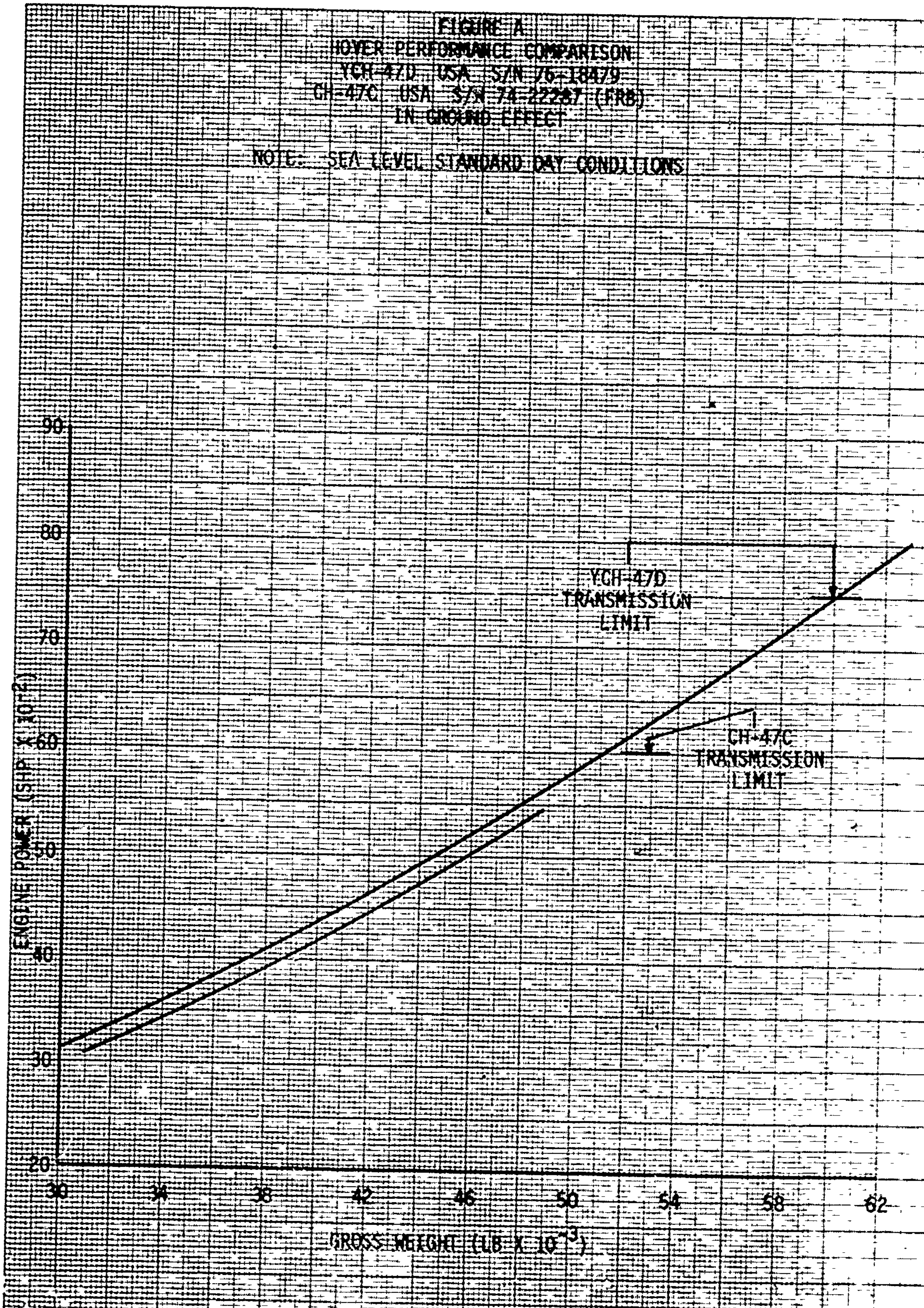
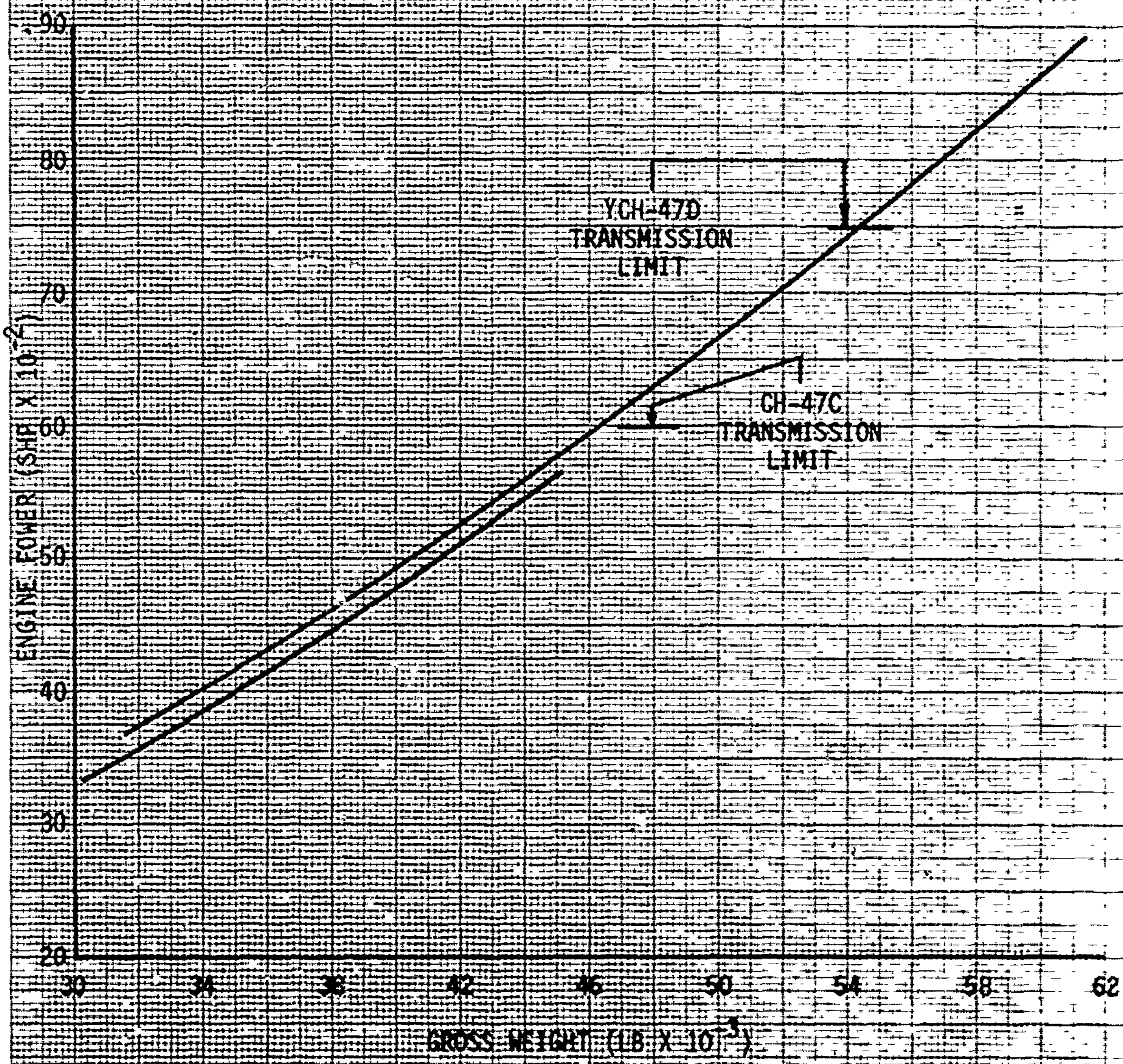


FIGURE A
HOVER PERFORMANCE COMPARISON
YCH-47D USA S/N 76-18479
CH-47C USA S/N 74-22287 (FRB)
IN GROUND EFFECT
NOTE: SEA LEVEL STANDARD DAY CONDITIONS
YCH-47D TRANSMISSION LIMIT
CH-47C TRANSMISSION LIMIT
ENGINE POWER (SHP X 10^-2)
GROSS WEIGHT (LB X 10^-3)
90
80
70
60
50
40
30
20
30
34
38
42
46
50
54
58
62

FIGURE 8
HOVER PERFORMANCE COMPARISON
YCH-47D USA S/N 76-18479
CH-47C USA S/N 74-22287 (FRB)
OUT OF GROUND EFFECT

NOTE: SEA LEVEL STANDARD DAY CONDITIONS



in the new/uprated transmissions, the independent cooling fans associated with the transmissions, and the increase in fuselage download created by the reduced nose-up pitch attitude of the YCH-47D at hover. However, the increased transmission torque limit more than compensates for the higher power required and increases hover gross weight capability from 48,890 pounds to 62,070 pounds at IGE hover under sea level standard conditions. The OGE hover capability is increased from 45,270 pounds to 54,650 pounds under the same conditions. The 54,650 pound hover OGE capability exceeds the 50,000 pound specification guarantee by 4650 pounds (9.3%). The YCH-47D has an improved hover capability when compared to the CH-47C with FRB.

Level Flight Performance

17. The level flight performance test results are presented in figures 3 through 6 for a constant $N/\sqrt{\theta}$ of 225. Data are also presented in figures 7 and 8 for a constant $N/\sqrt{\theta}$ of 235 and 245, respectively. Figures 9 and 10 are comparisons of level flight polars flown with the XM 198 Howitzer and polars at an equivalent referred gross weight without an external load.

18. Figure C presents a comparison of the YCH-47D level flight performance with that from the CH-47C with FRB. Both are at an average referred gross weight of 33,000 pounds. As with the hover comparison, the level flight performance shows an increased power requirement for the YCH-47D. This increased power requirement varies from approximately 90 SHP at 80 knots true airspeed (KTAS) to 270 SHP at 140 KTAS. If the transmission losses discussed in the hover tests are subtracted, the remaining additional power increment is a function of airspeed. The YCH-47D presents an increased drag due to the additional cargo hooks and the application of rough textured infrared paint.

19. The V_H at an average gross weight of 33,000 pounds was 157.5 KTAS under sea level standard conditions (maximum continuous power). This exceeds the specification guarantee of 155 KTAS by 2.5 KTAS (1.6%). The vibrations in level flight at all weights tested were acceptable at airspeeds to 145 KIAS (VRS 4 to 5). At airspeeds greater than 145 KIAS, the vibration level increased rapidly, reaching unacceptable levels (VRS 9) at V_H. In most cases tested, the 6 per rev (22.5 Hz) vibration was dominant with the 3 per rev (11.25 Hz) also exhibiting significant levels (paras 53 and 54).

20. Level flight performance was also evaluated with an XM 198 Howitzer as the external load. The Howitzer was carried in the tandem hook configuration with the tube pointed forward. The Howitzer weighed 15,355 pounds and represented an equivalent flat plate drag area of approximately 50 ft^2. The maximum level flight airspeed in this configuration was 144 KTAS at sea level standard conditions. The handling qualities with external loads are discussed under mission maneuvers (para 47). The level flight performance of the YCH-47D with the XM 198 Howitzer external load is satisfactory.

Climb Performance

21. The OEI climb performance was calculated from level flight power requirements (plus a power increment equivalent to a 100 fpm rate of climb (ROC)) using power available from the engine manufacturer's Prime Item Development Specification (PIDS) (ref 9, app A). Best ROC airspeed was established at the minimum power required airspeeds obtained during level flight performance. The results are presented in figure 11. The OEI service ceiling was determined to be

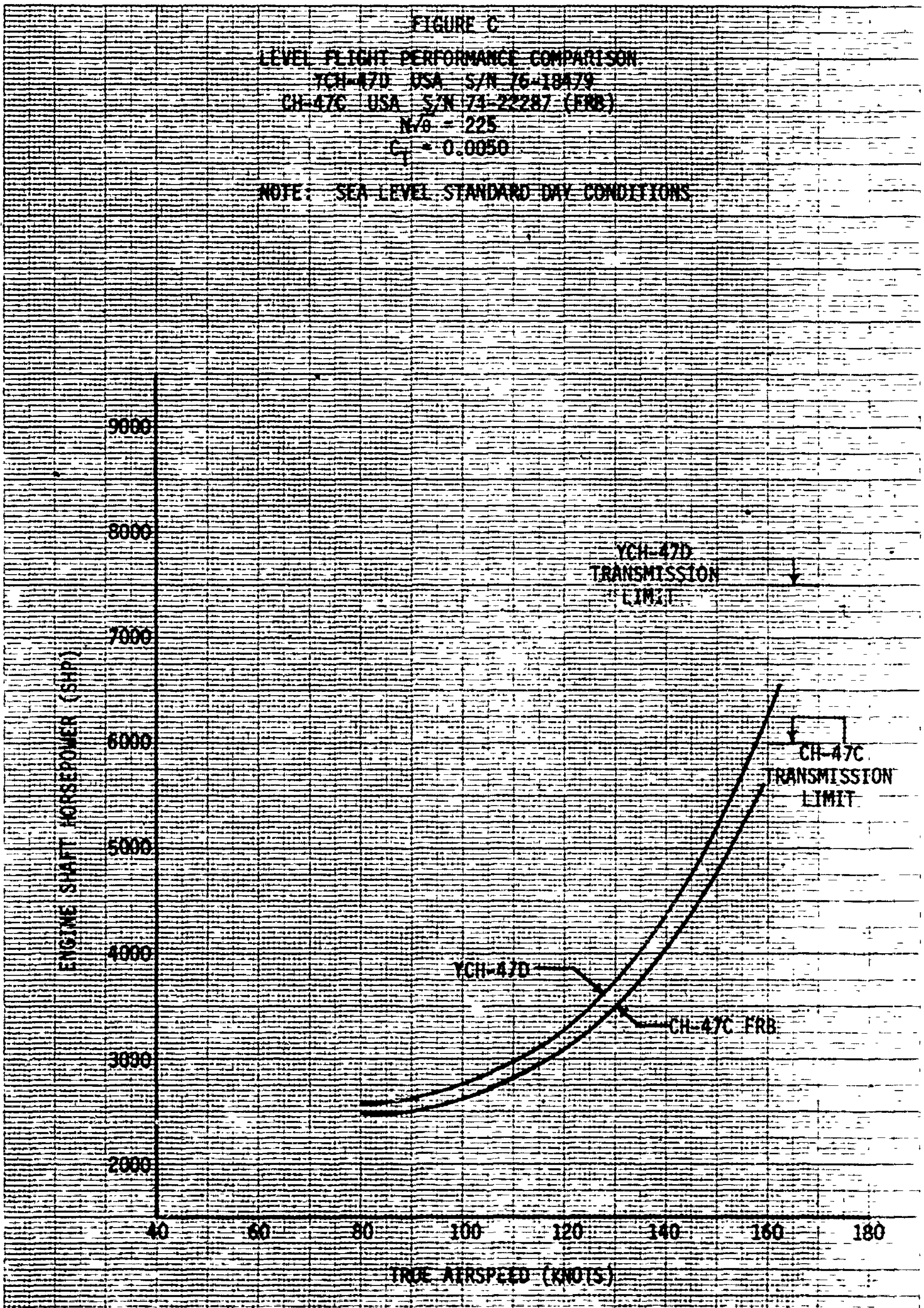


FIGURE C
LEVEL FLIGHT PERFORMANCE COMPARISON
YCH-47D USA S/N 76-18479
CH-47C USA S/N 74-22287 (FRB)
N/√θ = 225
C_T = 0.0050
NOTE: SEA LEVEL STANDARD DAY CONDITIONS
YCH-47D TRANSMISSION LIMIT
CH-47C TRANSMISSION LIMIT
YCH-47D
CH-47C FRB
ENGINE SHAFT HORSEPOWER (SHP)
9000
8000
7000
6000
5000
4000
3000
2000
40
60
80
100
120
140
160
180
TRUE AIRSPEED (KNOTS)

13,100 feet under standard day conditions at a gross weight of 33,000 pounds. This exceeds the guaranteed service ceiling of 10,000 feet by 3,100 feet (31%). The OEI climb performance of the YCH-47D exceeds the service ceiling guarantee and is satisfactory.

Mission Performance

22. The mission I requirements, as defined in figure D, were calculated from hover and level flight performance data using the engine manufacturer's PIDS for power available. Both the mission requirement (200 fpm vertical rate of climb (VROC)) and Required Operational Capability (500 fpm VROC) were calculated. The external load was the XM 198 Howitzer, which approximated the flat plate drag area of 50 ft^2 (see para 20). The aircraft was capable of carrying an outbound external load of 16,529 pounds when the 200 fpm VROC was used. This exceeds the specification guarantee of 15,000 pounds by 1,629 pounds (10%). When the VROC was increased to 500 fpm, the load capacity decreased to 15,334 pounds. The fuel consumption and gross weight of the aircraft for each segment of the 200 VROC mission is shown in table 4. The mission I performance of the YCH-47D is satisfactory.

23. The mission III performance requirements are defined in figure D. The aircraft capabilities were calculated from hover and level flight performance data with power available obtained from the engine manufacturer's PIDS. Aircraft gross weight and fuel consumption for each segment of the mission is shown in table 4. The outbound load was calculated as 15,414 pounds with an inbound load of 7,704 pounds. This capability exceeds the specification guarantee of 13,000 and 6,500 pounds, by 2,414 pounds outbound and 1,207 pounds inbound (18%). The mission III performance of the YCH-47D is satisfactory.

HANDLING QUALITIES

General

24. The YCH-47D handling qualities were evaluated using standard test techniques described in reference 7, appendix A. All flight evaluations were conducted with the AFCS in the BOTH mode (both systems 1 and 2 operational) and with the heading and altitude hold modes disengaged. Internal ballast was used to provide average gross weights of 31,900 and 49,880 pounds, with a average center of gravity (cg) of 329.2 to 330.8 inches, respectively. The requirements of MIL-H-8501A as modified by the detail specification were met with the exception of longitudinal cyclic limit force and collective creep. The detailed test conditions are outlined in table 2 with data presented in figures 12 through 46 of appendix E.

Control System Mechanical Characteristics

25. All control forces were measured on the ground with the rotor static and external units furnishing electrical and hydraulic power. These values were qualitatively confirmed in flight. Forces were measured with a hand-held force gage and control positions were read from the control position instrumentation. The thrust control rod brake switch was depressed during thrust measurements and the control centering was ON. The AFCS was in the OFF position during all ground measurements. Results are presented in figures 12 through 15.

FIGURE D. MISSION REQUIREMENTS

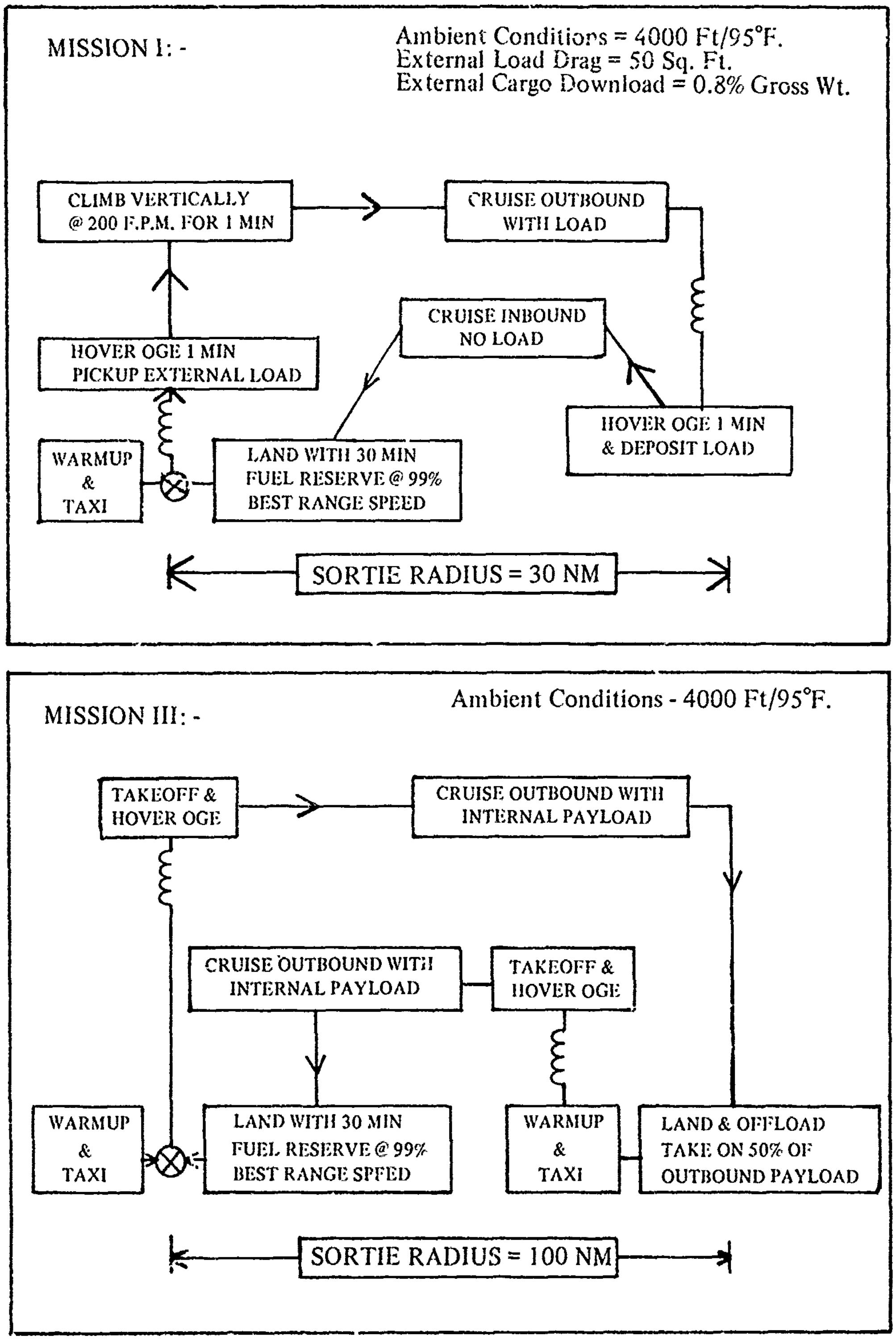


Table 4. Mission Performance

Mission I	4000 ft. 95°F	
Item	**Gross Weight (LB)**	**Fuel Used (LB)**
1. Engine start	42950	
2. Warm up and taxi	42865	85
3. Hover OGE for 1 min. and pick-up external load	42810	55
4. Climb vertically at 200 F. P. M for 1 min.	42754	56
5. Cruise outbound 30 N. M.	42043	711
6. Hover OGE 1 min.	41990	53
7. Deposit load	-16529 25461	
8. Cruise inbound 30 N. M no load	24988	473
9. 30 min. fuel reserve	23913	1075
10. Fixed useful load	-1290	
11. Empty	22623	
12. Total mission fuel		2508

Mission III	4000 ft 95° F	
Item	**Gross Weight (LB)**	**Fuel Used (LB)**
1. Engine start	44476	
2. Warm up and taxi	44391	85
3. Cruise out bound 100 N. M.	42315	2076
4. Land and offload 50% of load	-7707	
5. Engine start	34608	
6. Warm up and taxi	34523	85
7. Cruise inbound 100 N. M.	32739	1784
8. 30 min fuel reserve	31501	1238
9. Fixed useful load	-1340	
10. Load	-7707	
11. Empty	22454	
12. Total mission fuel		5268

26. The longitudinal breakout plus friction force was 1.8 pounds for forward motion and 2.0 pounds for aft motions. The force gradient for the first inch of travel from trim, both fore and aft, was at least equal to the breakout plus friction force. The forward and aft longitudinal stick force gradients were always positive and approximately one pound per inch aft and 1.3 pounds per inch forward. The gradients of the first inch of travel were greater than those for the remainder of travel, and there were no objectionable discontinuities. A maximum control force of 10 pounds was required for forward travel and 7 pounds for aft travel. The friction band varied from 0.6 pound for forward to 1.2 pound for aft motion.. The longitudinal control force characteristics failed to meet the requirements of the detail specification in that the limit cyclic control forces exceeded 8 pounds in the forward direction. However, the longitudinal control force characteristics of the YCH-47D are satisfactory.

27. The lateral breakout plus friction was approximately 0.9 pounds for right displacement and 1.8 pounds for left displacement. The lateral force gradients were approximately 1.0 to 1.25 pounds per inch of displacement with no objectionable discontinuities. A maximum control force of 7 pounds was encountered to the right with 6 pounds required to the left and the friction band varied from 1.0 to 1.25 pounds. The lateral control force characteristics of the YCH-47D met the requirements of the detail specification and are satisfactory.

28. The AFCS provides longitudinal and lateral vernier attitude adjustment capability through the use of the beep trim button ("Chinese hat") located on the top of the cyclic. The breakout force was qualitatively evaluated in all directions. The lateral breakout forces were too high and required the pilot to reorient the thumb and accomplish adjustments with a "push-pull" motion rather than a lateral motion of the thumb. The high lateral breakout force on the cyclic beep trim button is a shortcoming.

29. The directional breakout plus friction force was approximately 5 pounds. The force gradients were approximately 5 pounds per inch of displacement and displayed no objectionable discontinuities. A maximum force of 30 to 35 pounds was required for full control travel, and the control friction band varied from 2.5 to 5 pounds. The directional control force characteristics of the YCH-47D met the requirements of the detail specification and are satisfactory.

30. The thrust lever breakout plus friction was 5.5 pounds when started from the detent and moved upward and 4.0 pounds from the detent downward. At full up travel, the breakout plus friction was reduced to approximately 1.5 pounds. The limit control force was approximately 15 pounds. Since all measurements were taken with the thrust control rod magnetic brake switch depressed, the in-flight values were increased by the amount of the magnetic brake force. This combined force was adequate to maintain thrust rod position at all but the high power settings (greater than 80 percent torque). The collective creep at high power settings is a shortcoming. The mechanical characteristics of the thrust control failed to meet the requirements of the detail specification due to collective creep; however, they are satisfactory.

Control Positions in Trimmed Forward Flight

31. Trim control positions were evaluated in conjunction with level flight performance tests at the conditions in table 2. Representative data from two gross weights are presented in figures 16 and 17. The longitudinal control position gradient with airspeed was conventional in that increased forward control position

was required to trim at increased airspeeds. The average gradient was one inch of longitudinal stick displacement per 80 KCAS. Lateral control trim changes were less than 3/4-inch and directional control changes were linear with less than 1/4-inch displacement throughout the airspeed range evaluated. The pitch attitude change with airspeed was evident only above 90 KCAS and was linear to V_H with 6 degrees nose-down pitch change required between 90 KCAS and V_H. Longitudinal and lateral control trim positions varied slightly with longitudinal cg, but did not adversely affect the flying qualities of the helicopter. Collective inputs in level flight which caused a pitching moment were compensated for by the AFCS. The pitch attitude was automatically restored to that required to maintain the trim airspeed. The trim control position characteristics of the YCH47D are satisfactory.

Static Longitudinal Stability

32. Static longitudinal stability characteristics were evaluated in level flight at two gross weights and two cg locations. Test conditions are listed in table 2 and the results are presented in figures 18 and 19. The variation of longitudinal control position with airspeed at fixed collective indicated that the aircraft possesses static stability. The variation of lateral and directional control position with airspeed was minimal for all conditions tested. Pitch attitude was essentially constant at the slower airspeeds and became increasingly nose down at airspeeds above 90 KCAS. The static longitudinal stability characteristics of the YCH-47D met the requirements of the detail specification and are satisfactory.

Static Lateral-Directional Stability

33. Static lateral directional stability characteristics were evaluated at the conditions listed in table 2, with the results presented in figures 20 through 23. The directional control position variations with sideslip at all airspeeds tested were essentially the same, indicating linearity and positive directional stability. The dihedral effect was also positive in that increasing right lateral control was required for increasing right sideslip. Longitudinal control displacement with sideslip was minimal and sideforce characteristics, as indicated by bank angle, were also linear and positive. At the low airspeed and high gross weight (64 KCAS), the variation of bank angle with sideslip was small, providing minimum pilot cues to uncoordinated flight at sideslip angles to 15 degrees. At an airspeed of 119 KCAS, the sideforce cues were stronger and readily apparent at sideslip angles greater than 5 degrees. The static lateral-directional characteristics of the YCH-47D met the requirements of the detail specification, and are satisfactory.

Maneuvering Stability

34. The maneuvering stability characteristics were evaluted at the conditions listed in table 2. with the results presented in figure 24. AT 121 KCAS the gradient was neutral. The AFCS "turn with one control" capability is indicated by the neutral directional control position gradient and only slight changes in the lateral control position. Turns with more than 30 degrees bank (AFCS ON) were easy to establish and maintain (HQRS 3). Maneuvering flight characteristics of the YCH-47D met the requirements of the detail specification and are satisfactory.

Dynamic Stability

35. The dynamic stability characteristics were evaluated at the conditions listed in table 2. The aircraft short-period response was investigated in all axes. The long period longitudinal and lateral-directional oscillations were also tested.

36. The longitudinal and lateral short-period response was essentially deadbeat at heavily damped. Representative response to one inch longitudinal, lateral, and directional pulse inputs are contained in figure 25.

37. Lateral-directional dynamic characteristics were evaluated at trim airspeeds of 60 and 121 KCAS using release from steady heading sideslip and a pedal doublet inputs. At all conditions tested, the response was heavily damped with one or two overshoots before the aircraft returned to the heading commanded by the AFCS.

38. Long-period response characteristics were evaluated at trim airspeeds of 60 and 121 KCAS. The response was heavily damped and returned to trim with one overshoot. The dynamic stability characteristics of the YCH-47D met the requirements of the detail specification and are satisfactory.

Controllability

39. Controllability was evaluated under the conditions shown in table 2 with the results presented in figures 26 through 46. Controllability was found to be relatively independent of airspeed or gross weight variations.

40. Longitudinal controllability data are presented in figures 26 through 31. Control sensitivity varied from 20 to 25 degrees/seconds^2 per inch of control displacement for both fore and aft inputs with an average time to maximum acceleration of 0.05 second. Maximum rates were achieved in approximately 0.35 seconds with control responses of approximately 8 degrees/sec per inch of control input. Control power was approximately 3 to 5 degrees of pitch attitude change after one second, per inch of control displacement. The longitudinal controllability of the YCH-47D met the requirements of the detail specification and is satisfactory.

41. Typical time histories of 1/2 and 1 inch longitudinal step inputs are presented in figure 32. The pitch rate shows a rapid response after the step input with a peak reached after approximately 0.3 seconds. This response is a result of the control quickening provided by the AFCS. After this initial rate is obtained, the pitch rate is decreased to approximately one-half the initial value as the Differential Airspeed Hold (DASH) begins to take effect (see app B, para 7).

42. The lateral controllability data are presented in figures 33 through 38, with a typical time history for one-half and one-inch inputs shown in figure 39. Control sensitivity varied from 25 to 30 degrees/second^2 per inch of input with times to maximum acceleration of approximately 0.05 second. Maximum rates were achieved in approximately 0.7 to 0.9 seconds with control responses of 15 to 20 degrees/second per inch of control input. Control power was 2 to 3 degrees of roll attitude change after 0.5 seconds, per inch of control input. The lateral controllability of the YCH-47D met the requirements of the detail specification and is satisfactory.

43. The directional controllability data are presented in figures 40 through 45, with a typical time history of one-half and one inch step inputs shown in figure 46. Control sensitivity was approximately 15 degrees/second^2 per inch of control input with maximum accelerations obtained after 0.1 second. Control responses of 15 degrees/second were obtained within 1.3 to 1.5 seconds after control input. Control power of approximately 8 degrees of yaw were obtained after one second, per inch of control input. The directional controllability of the YCH-47D met the

requirements of the detail specification and is satisfactory.

Ground Handling Characteristics

44. The ground handling characteristics were evaluated over a range of gross weights from 31,000 to 52,000 pounds (2000 pounds above maximum allowable gross weight for test purposes only). The aircraft was easy to maneuver under all conditions tested. However; at the light gross weights, the aircraft exhibited a tendency to become light on the aft wheels. This produced a loss of effective steering when the right rear wheel became airborne and also programmed the longitudinal speed trim and DASH actuators to the fly position. The latter conditions required a longitudinal control input to effectively maintain aircraft attitude. The tendency of the longitudinal speed trim and DASH to program to the fly position at light gross weights is a shortcoming.

Low-Speed Flight Characteristics

45. Low-speed flight characteristics were qualitatively evaluated both longitudinally and laterally. The heading hold feature of the AFCS allowed lateral low-speed flight without directional control inputs. The helicopter was an extremely stable platform under all conditions tested and allowed "hands-off" flight at a hover for short periods. With the radar altimeter hold mode of the AFCS engaged, the helicopter maintained altitude within ±5 feet. The low-speed flight characteristics of the YCH-47D are satisfactory.

Power Management

46. The power management characteristics were qualitatively evaluated throughout the test program. Torque matching of the engines was satisfactory at power settings above 50 percent torque. At lower power settings, the torque split was unacceptable and reached values greater than 15 percent torque. This torque split required constant monitoring and adjustment during approaches (HQRS 5). Rotor droop of ±4 rpm was encountered during rapid power changes. The poor power management characteristics of the T55-L-712 engines at low power settings is a shortcoming as previously documented (ref 10, app A).

Mission Maneuvering Characteristics

47. Mission maneuvers consisted of both single and tandem load hook-ups and climbing and descending turns with external loads. Loads consisted of: high density, 8000 pound, single point hook-ups; fore and aft, high density, 8000 pound hook-ups; and, tandem loading with the XM 198 Howitzer. Hook-ups were conducted in winds to 17 knots with minimal pilot compensation required (HQRS 3). Climbing and descending turns with the XM 198 in tandem were evaluated at 120 KIAS with climbs and descents to 1500 feet per minute and bank angles to 30 degrees left and right. Similar maneuvers were conducted with single point loads on the aft and/or forward hooks. No handling qualities or load stabilization problems were encountered during these tests. The mission maneuvering characteristics of the YCH-47D are satisfactory.

AIRCRAFT SYSTEM FAILURES

Simulated Engine Failures

48. Single engine failures were simulated by disabling the normal engine beep trim and using the emergency beep trim to reduce the engine speed to minimum. The engine failure was easily detected under high power conditions by a noise reduction, a reduction in rotor speed and a torque split. Under conditions of low power, such as an approach or descent, the identification was more difficult due to the reduced noise level and the torque split associated with power management (para 46). The engine failure characteristics of the YCH-47D are satisfactory.

Advanced Flight Control System (AFCS) Failures

49. Failures in the AFCS were simulated by selecting either a single system or disengaging the total system with the selector switch on the AFCS panel. Single system failures produced no changes except for illumination of the associated caution light. Dual system failure resulted in an unaugmented aircraft and handling characteristics comparable to other CH-47 aircraft. Aircraft control could be maintained with moderate pilot compensation (HQRS 4) in pitch and roll and with considerable compensation (HQRS 5) required in yaw. Reengagement of the AFCS presents a potential problem as discussed below (para 50). The AFCS failure characteristics of the YCH-47D are satisfactory.

50. The simulation of dual AFCS failures was found to present a potentially hazardous situation to an uninformed crew. If the airspeed is changed appreciably between simulation of the failure and reengagement of the AFCS, a large pitch change will be induced by the DASH actuator upon engagement, An airspeed change from 40 to 140 KIAS produces an abrupt pitch change of 30 degrees requiring a rapid longitudinal stick input of approximately 4 inches to arrest the pitch rate. At low altitudes this pitch input could result in aircraft damage. The following WARNING should be added to the operator's manual:

WARNING

"Re-engagement of the AFCS at an airspeed appreciably different from that of disengagement will result in extreme pitch inputs."

AUTOROTATIONAL CHARACTERISTICS

51. Autorotational entries were evaluated by rapidly lowering the thrust control to the detent position. With the aircraft trimmed for level flight, there were no unusual attitude changes and the AFCS established an autorotational attitude in an attempt to hold airspeed. Minimal pilot compensation (HQRS 3) was required to transition from level flight to an autorotational descent. With the altitude hold feature of the AFCS selected, the reduction in thrust (release of thrust magnetic brake) disengaged the altitude hold and the entry procedure was identical to that discussed above. When the thrust brake was released after entering the autorotation, the AFCS increased thrust in an attempt to maintain altitude. This action caused a reduction in rotor speed, but was easily overpowered by the pilot. The autorotation entry characteristics of the YCH-47D are satisfactory.

52. Autorotational descent characteristics were evaluated at an average gross weight of 32,200 pounds and 5000 feet pressure altitude. The autorotational descent was established by lowering the thrust lever to the detent and then decreasing engine speed with the emergency governor until clutch disengagement was accomplished. The airspeeds flown during these tests could be easily trimmed and minimal pilot compensation was required to maintain trim airspeed ±2 KIAS (HQRS 2). Autorotational rpm could be maintained at 225 ±5 rpm only through considerable pilot effort (HQRS 5), due to extreme sensitivity of the rotor speed to airspeed and pitch attitude variations. The autorotational descent characteristics of the YCH-47D are satisfactory.

VIBRATION

53. Throughout the conduct of the PAE, vibrations were evaluated qualitatively and quantitatively in the cockpit and cabin areas. One flight of 2.2 hours was dedicated to vibration evaluation under the conditions of table 2, with the aircraft ballasted to the 33-troop configuration. Vibration accelerometers and their locations are listed in appendix C. Table 5 presents a tabulation of the vibration specification compliance, and sample data are presented in figures 47 through 54, appendix E.

54. The vibration levels were found to be acceptable and within the limits of the detail specification and MIL-H-8501A up to an airspeed of 145 KIAS. Above this airspeed, vibrations were excessive reaching unacceptable levels prior to V_H. The predominent vibration was at 6 per rev frequency under most conditions tested, although the 3 per rev vibrations were also high. Vibration levels were of sufficient magnitude to effectively restrict the helicopter to 145 KIAS for continuous operations. The vibration levels met the requirements of MIL-H-8501 and the detail specification at airspeeds to 145 KIAS. The high vibration levels, which do not meet specification requirements at airspeeds above 145 KIAS, is a shortcoming.

HUMAN FACTORS

Cockpit and Cabin Evaluation

55. The cockpit and cabin area were evaluated for function and location of switches and instrumentation during all phases of the test program. The 8 shortcomings described below were peculiar to the YCH-47D and are in addition to shortcomings which have not been corrected on previous CH-47 models.

56. The number 1 and 2 AC bus ties (photo 1) are gang-bar type circuit breakers which control the associated AC electrical system. The circuit breakers are located in the power distribution panels and are ON in the up position. The location and lack of protection makes the circuit breakers susceptible to inadvertent activation which would result in total loss of the associated AC system. A guard-bar over the bus tie relays would avoid this problem. The lack of protection for the AC bus tie relay circuit breakers is a shortcoming.

57. The emergency power lights (photo 2) located on the center console above the Power Turbine Inlet Temperature (PTIT) indicators, provide the crew with an indication when the engine has reached 900±10±C PTIT and is producing emergency power. Since the engines will be PTIT limited under certain conditions, the emergency power lights will be the first indication of emergency power. The pilot's scan during these high power operations will be on the primary instruments and outside the cockpit allowing the emergency power indication to be overlooked.

Table 5. Vibration Characteristics[1]

Flight Condition	Station	Airspeed (KTAS)	Allowable Acceleration (g)[2] Vertical and Lateral		Maximum Accelerations (g) Vertical		Maximum Accelerations (g) Lateral	
			3/Rev	1/Rev	3/Rev	1/Rev	3/Rev	1/Rev
Level flight	95	0-40	0.25	0.065	0.112	0.025	0.083	0.017
		40-139	0.15	0.065	0.048	0.021	0.044	0.013
		140-155	0.20	0.065	0.104	0.056	0.098	0.025
	320	0-40	0.25	0.065	0.069	0.027	0.088	0.010
		40-139	0.15	0.065	0.040	0.036	0.064	0.080
		140-155	0.20	0.065	0.144	0.046	0.198	0.080
Acceleration	95	40-140	0.40	0.10	0.128	0.031	0.188	0.019
	320	40-140	0.40	0.10	0.108	0.028	0.196	0.021
Partial power descent: Descent rate (fpm)								
500	95	60	0.15	0.065	0.032	0.022	0.031	0.011
1000			0.15	0.065	0.120	0.018	0.102	0.011
1500			0.15	0.065	0.045	0.019	0.08	0.007
500	320	60	0.15	0.065	0.013	0.010	0.087	0.008
1000			0.15	0.065	0.041	0.020	0.100	0.012
1500			0.15	0.065	0.100	0.016	0.111	0.010
500	95	100	0.15	0.065	0.029	0.025	0.039	0.005
1000			0.15	0.065	0.082	0.025	0.069	0.015
1500			0.15	0.065	0.074	0.010	0.069	0.008
500	320	100	0.15	0.065	0.018	0.015	0.056	0.008
1000			0.15	0.065	0.05	0.025	0.083	0.009
1500			0.15	0.065	0.103	0.022	0.087	0.008

Notes:
[1] Average weight = 39,280 pounds, average density altitude = 2000 feet; rotor speed = 225 rpm
[2] As specified in Boeing Document 145-PJ-7103, paragraph 3.3.2.1 modifying paragraph 3.7.1, Specification MIL-H-8501

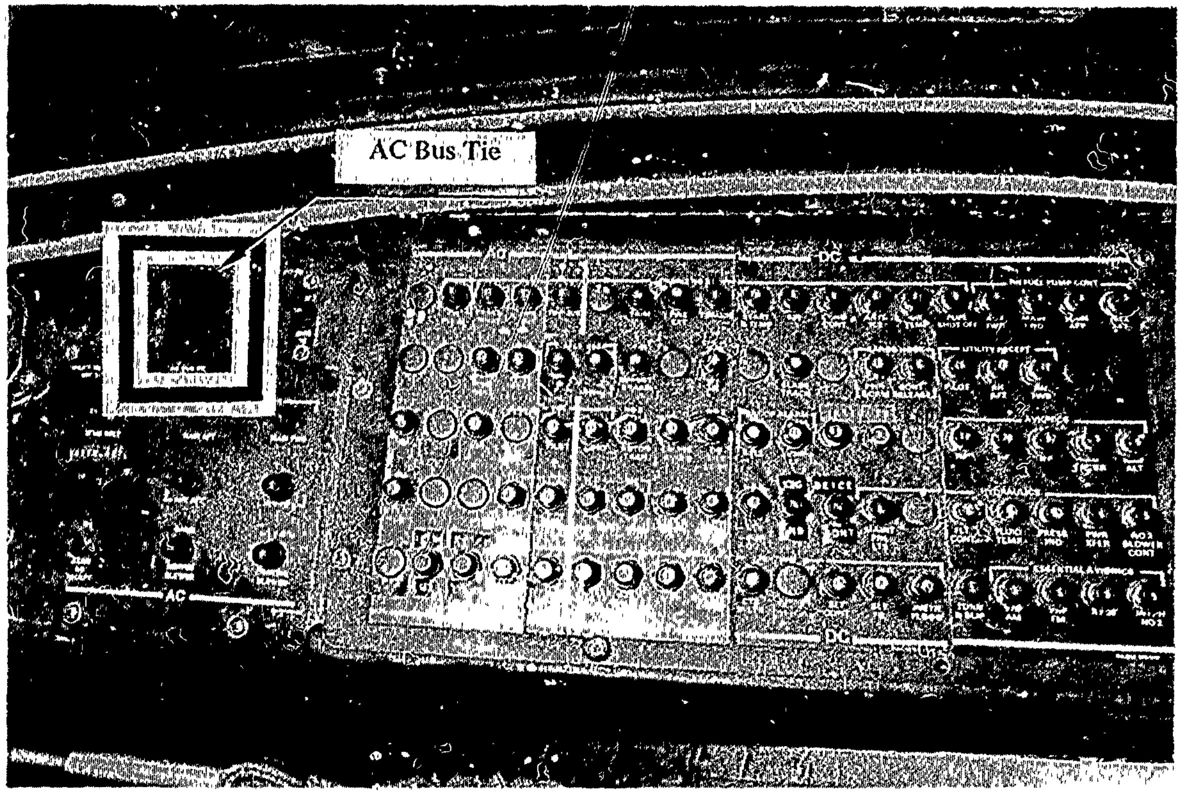


Photo 1. Power Distribution Panel.

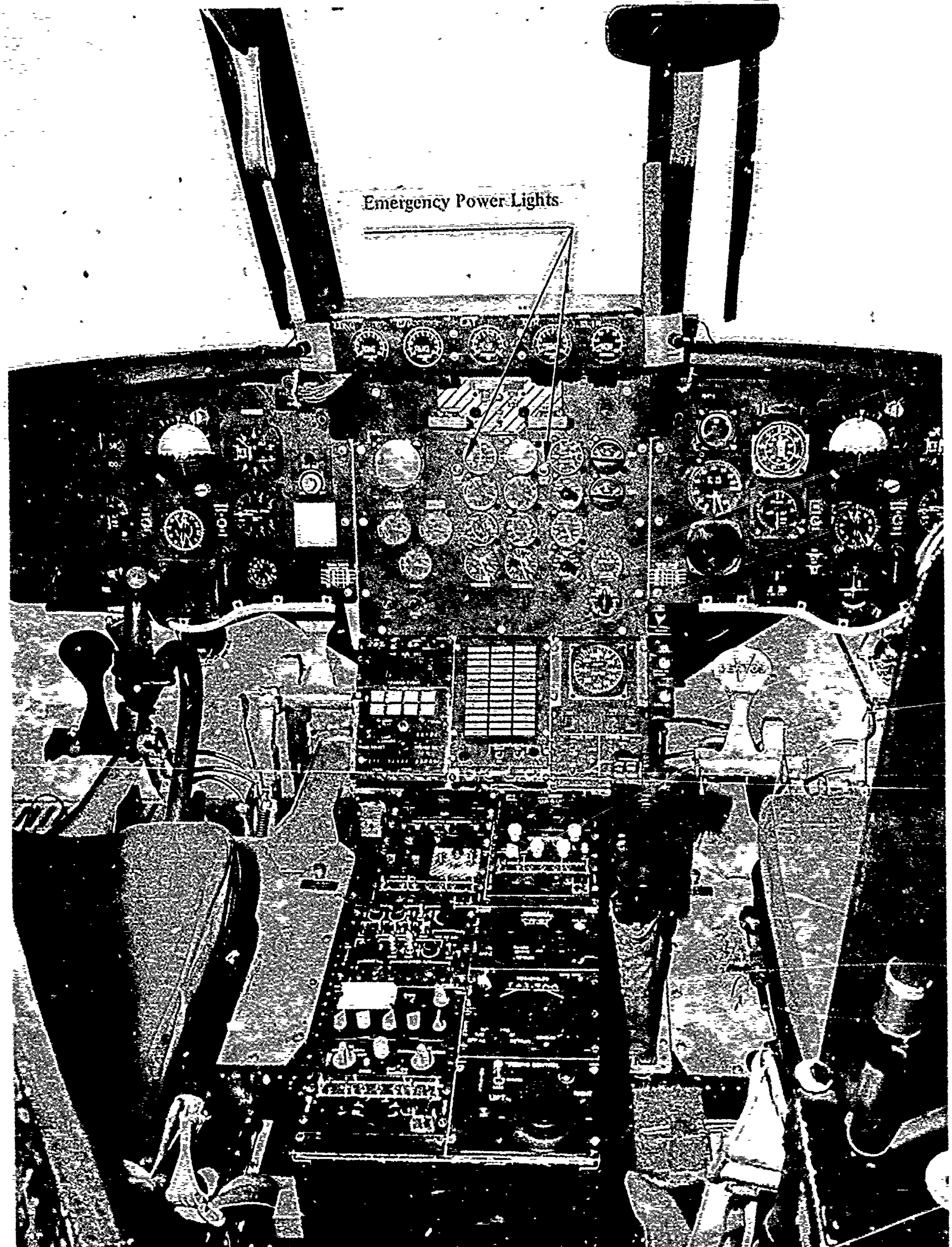


Photo 2. Center Console.

Locating these lights over the engine torque gages would eliminate this problem. The poor location of the emergency power lights is a shortcoming.

58. The hydraulic panel (photo 3) located on the overhead switch panel contains brake/steer and ramp isolation switches. These switches are designed to allow isolation of the associated components in the utility hydraulic system under combat conditions. In the event of a ruptured line in one of these subsystems, the entire utility hydraulic system would not be lost. The loss of the entire utility system is not a major failure thus the addition of these switches is an unnecessary complication to the cockpit environment and checklist procedures. If such an isolation system is deemed mandatory, it should be of an automatic type requiring no action by the crew. The addition of the brake/steer and ramp isolation switches is a shortcoming.

59. The utility and flight control hydraulic pressure gages (photo 4) have been removed from the center console (photo 2) and placed on the maintenance panel located in the aft cargo compartment. Caution lights now provide a cockpit indication of the total failure of these systems; however, there is no cockpit indication of pending failure or improper functioning in these systems as was provided by the gages. The removal of the utility and flight control hydraulic pressure gages from the cockpit is a shortcoming.

60. The longitudinal stick position indicator (photo 5) is located on the right side of the sloping console and protrudes approximately 1/2 inch aft of the plane of the console. This location of the indicator is necessary to allow viewing by both pilots; however, it makes the glass tube of the indicator susceptible to impact damage from the pilot entering his station. The susceptibility of the longitudinal stick position indicator to impact damage is a shortcoming.

61. The maintenance panel located in the aft right side of the cargo area allows the flight engineer to monitor aircraft systems during flight. The aft location of this panel precludes its use when the flight engineer is monitoring an external load (prone over the cargo hole). The poor location of the maintenance panel is a shortcoming.

62. The starter ON lights (photo 3) located on the start panel of the overhead switch panel provide the crew with an indication that the engine starter is engaged. The location of these lights prevent their effective use because the pilot's scan is on the engine instruments during the start sequence. Relocation to the vicinity of the PTIT gages would allow more effective use. The poor location of the engine starter lights is a shortcoming.

63. The APU ON light (photo 2) on the caution panel does not provide a caution indication It is an advisory light and as such should be green instead of yellow. The color of the APU ON light is a shortcoming.

Night Cockpit Evaluation

64. Cockpit lighting was evaluated at night with blackout curtains installed on all window areas and the entrance to the cockpit. Electrical power was supplied by an external power source. Table 6 contains a listing of the problem areas encountered. The problems listed consist of those peculiar to the YCH-47D, those common to all CH-47 helicopters, and those that may be attributed to government furnished equipment. Consideration should be given to the incorporation of a system compatible with night vision goggles consisting of uniformly lighted instruments and

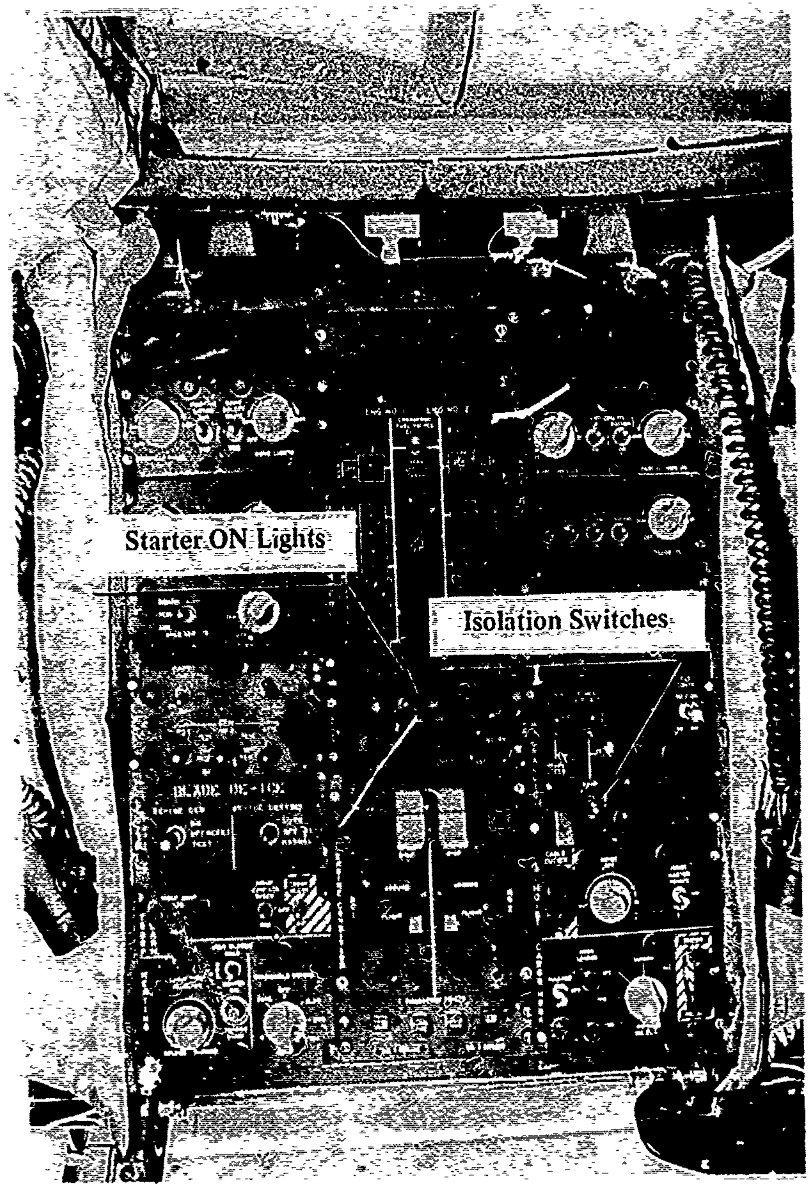


Photo 3. Overhead Console.

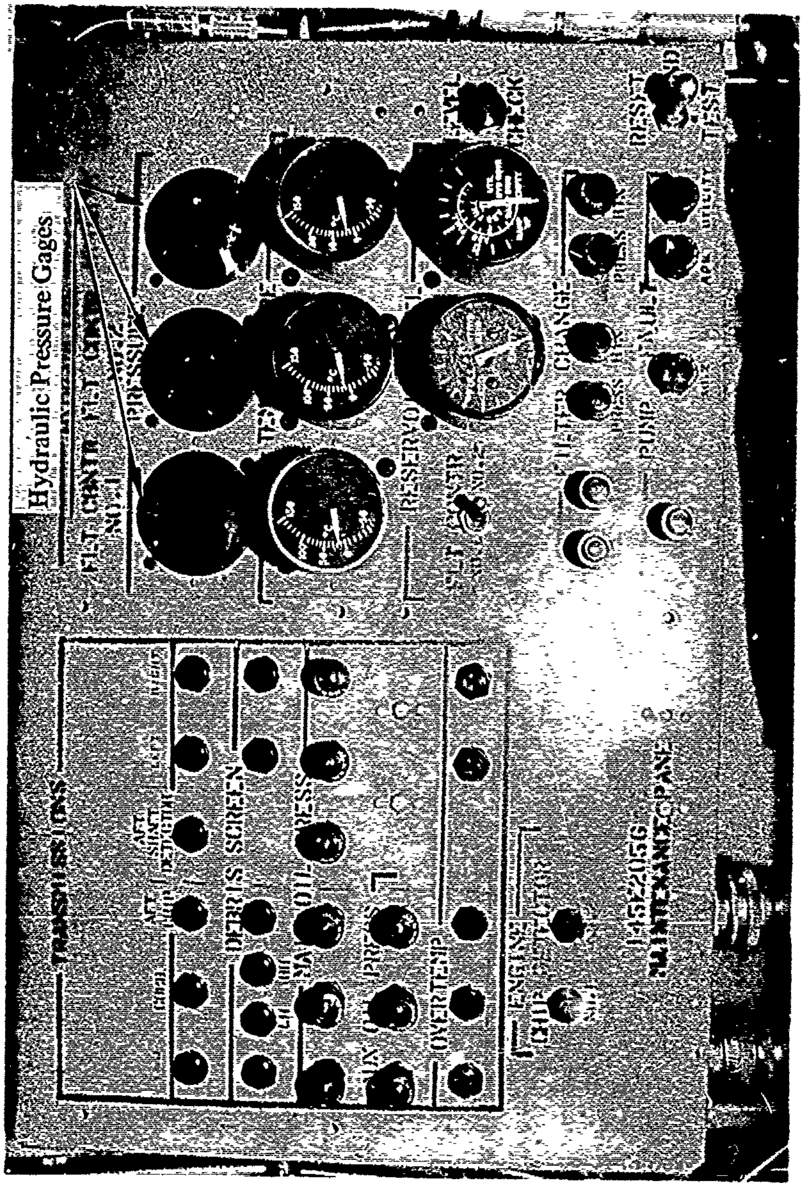


Photo 4. Maintenance Panel.

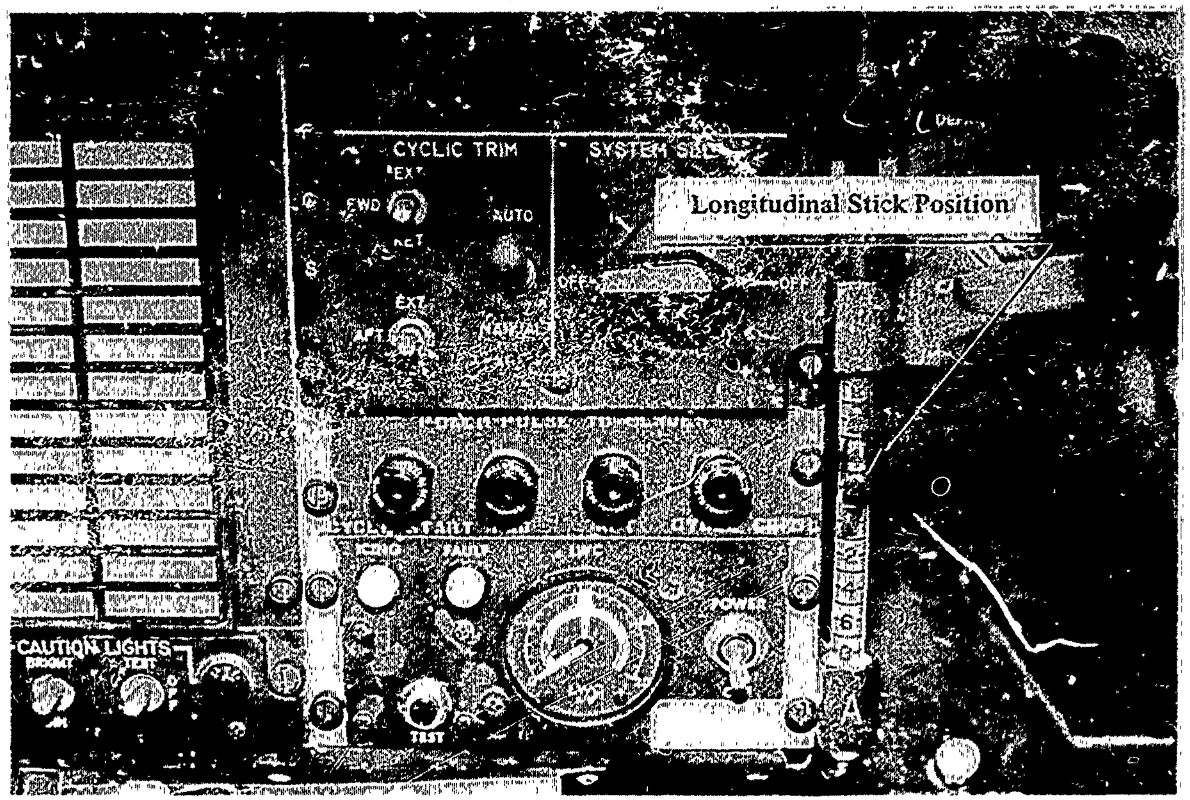


Photo 5. Longitudinal Stick Position Indication.

Table 6. Cockpit Lighting Evaluation

Problem Area	Reason
Map and Dome lights not operable with battery switch in BATT only position.	Lighting needed during pre-flight post-flight and emergency operations.
Overhead console floodlights improperly aimed.	Control panels inadequately lighted.
Lighting not balanced between integrally lighted and post/brow lit instruments.	Integral lighting as much as ten times the intensity of other lighting.
Engine emergency trim panel too bright.	Reflects on center windshield.
Light leak on leading edge of overhead console.	Reflection washes out entire center windshield.
*Transmission oil pressure and temperature selector switches not dimmable.	Lighting too bright, washes out engine instrument lighting.
**ADF control head lighting too bright.	Reflects on center windshield.
*Bottom half of airspeed and torque indicators unreadable.	Poor light distribution from post/brow lights.
**VHF digits not readable in NAV radio.	Digits set too low in light plate to receive illumination.
*Cross hatching on heater, troop alarm and cargo hook panel not visible.	Panels cannot be readily identified.
*Upper and lower legends on lighting control panel unreadable.	Poor light distribution makes lighting selection difficult.
*Bright spot around heater start button.	Button highlighted
*Caution lights, advisory panel and fire handles not continuously dimmable.	Too bright for some night operations.

*Problem areas are common to previous models of the CH-47

**Problem areas that may be attributed to government furnished equipment (GFE).

variable intensity throughout the required range. The poor YCH-47D cockpit lighting is a shortcoming.

Noise

65. The aircraft internal noise level was evaluated under the conditions outlined in table 2 with complete internal insulation installed. Measurements were taken at the aircraft centerline, 40 inches above the floor. Data from fuselage station 85, 105, 260, 300 and 482 are shown in figures 55 and 56, appendix E, for 140 KIAS. Data from stations 85, 105, 180, 300 and 482 are shown for V_H (155 KIAS) in figures 57 and 58, appendix E. The requirements of the specification were not met at the 125 to 1000 Hz and at the 4000 Hz levels. The excesses were slight (+3Db) at the specification fuselage stations, and in general the internal noise level met the specification guarantees. It should be noted that there was little apparent reduction in the cockpit noise levels from that observed in previous models of the CH-47 (see ref 11, app A). The noise is of a sufficient intensity to require the wearing of ear plugs in conjunction with the SPH-4 helmet to prevent temporary hearing losses. The high cockpit noise level in the YCH-47D is a shortcoming (see para 68).

RELIABILITY AND MAINTAINABILITY

66. Although dedicated reliability and maintainability (R&M) data was not collected, the R&M characteristics of the aircraft were qualitatively evaluated throughout the test program. These observations were recorded as equipment performance reports (EPR's) and are summarized in appendix F. The three most serious maintenance problems encountered during the test were: the potential R&M implications of the bellcrank motion at station 482; the input pinion seal leaks on the forward transmission; and the horizontal hinge pin cap loss of torque. These areas should receive special attention during the reliability and maintainability testing to be conducted.

SUBSYSTEMS TESTS

Pitot-Static System

67. The swivel head pitot-static boom and standard ship airspeed system were calibrated in level flight by the contractor utilizing a Navy Theodolite range. The pitot-static boom was found to possess a fairly constant airspeed error of 20 knots while the ship's system error varied from 10 knots at 40 KIAS to zero at 120 KIAS. Due to the magnitude of the pitot-static boom error, the standard ship system was used as reference during all tests. The contractors calibration was verified at three airspeeds using a surveyed ground speed course. The data for the standard ship's system is shown in figure 59. appendix E. The standard ship's airspeed system is satisfactory.

Interphone System

68. The interphone system was evaluated during all phases of testing and was found to contain two shortcomings. The noise level in the cockpit area is sufficient to require the use of earplugs in conjunction with the SPH-4 helmet to avoid temporary hearing loss (para 65). With the combination of earplugs and helmet, the interphone set (C6533/ARC) has insufficient volume to allow monitoring of either interphone or radio communications. The insufficient volume of the interphone set (C6533/ARC) is a shortcoming.

69. The interphone set also lacks the capability to mute the interphone conversations. This requires all crewmembers to monitor interphone conversations at all times and results in cluttered communications during many combat or external load operations. The lack of a mute capability in the interphone set (C6533/ARC) is a shortcoming.

Tandem Hook System

70. The fore and aft hooks were evaluated during single hook operation (8000 lb fore and aft), dual hook operation (8000 lb each on both fore and aft), and tandem hook operations (XM 198 Howitzer). The visibility of both the fore and aft hook is poor from the normal crew chief position (prone on the floor near the cargo hold). This difficulty is best illustrated during tandem operations since only one hook can be viewed from a single point on the floor. This situation could lead to fuselage/load contact during tandem operations since the load clearance is minimal during hook-up on loads such as the XM 198. The poor visibility of the fore and aft hooks during tandem hook operations is a shortcoming.

Radar Altimeter System

71. The radar altimeter was found to be unreliable during external load operations using the tandem configuration. This was caused by the tendency of the altimeter signal to lock onto the external load. This eliminated the instrument's use during low level tandem hook operations when it could potentially have provided valuable information. The unreliability of the radar altimeter during tandem external load operations is a shortcoming.

Advanced Flight Control System (AFCS)

72. The AFCS was evaluated throughout the test program and found to greatly reduce pilot workload and improve mission capability. The system provided a very stable platform for all modes of flight tested and allowed "hands-off" flight capability. The AFCS is an enhancing characteristic.

73. The altitude hold feature of the AFCS applies thrust through the Collective Control Drive Actuator (CCDA) to maintain altitude. This feature does not provide engine or drive system protection and thus could overtorque or overtemp the engines under extreme operational conditions. The operator should be made aware of this possibility by addition of the following NOTE to the operator's manual:

NOTE

> "The altitude hold feature of the AFCS does not provide engine or drive system protection and may produce engine overtorque or overtemp under extreme operating conditions.

74. The AFCS receives pitch inputs from the attitude indicators (VGI). The visual pitch reference of the VGI may be manually adjusted by the crew to compensate for changes in pilot seating and aircraft loadings. This manual adjustment produces a pitch input to the AFCS which is a disconcerting and requires pilot action to retrim to the desired attitude. The pitch inputs to the AFCS by manual adjustment of the VGI is a shortcoming.

Power Steering System

75. The power steering capability of the right aft gear is controlled by a three-position switch that also provides lock and unlock positions. To activate the power steering from the aft wheels locked position requires the crew to stop the switch in the unlock position for five to seven seconds to allow for value sequencing in the system. During this period the crew has no indication of the mode of operation of the gear. During taxi operations the aircraft may be in motion with the aft gear unlocked for five to seven seconds, thus rendering ground control of the helicopter impossible. The lack of a capability to immediately switch from the locked to the steer mode on the aft gear is a deficiency.

CONCLUSIONS

GENERAL

76. The following conclusions were reached upon completion of the YCH-47D PAE:

a. There was one deficiency and twenty shortcomings.

b. There was one enhancing characteristic.

c. The YCH-47D provides improved hover capability when compared with the CH-47C equipped with FRB and T55-712 engines (para 16).

d. The maximum level flight airspeed (V_H) is increased at high gross weights (above 40,000 lb) when compared with the CH-47C equipped with FRB and T55-712 (para 19).

e. The YCH-47D exceeded the performance guarantees for the following areas (table 3).

(1) Mission performance.

(2) Maximum level flight speed (V_H).

(3) One engine inoperative ceiling.

(4) OGE hover capability.

ENHANCING CHARACTERISTICS

77. The AFCS is an enhancing characteristic (para 72).

DEFICIENCIES

78. The lack of a capability to immediately switch from the locked to the steer mode on the aft gear (para 75) is a deficiency.

SHORTCOMINGS

79. The following shortcomings were identified and are listed in order of decreasing importance:

a. The poor YCH-47D cockpit lighting (para 64).

b. High vibration levels which do not meet specification requirements at airspeeds above 145 KIAS (para 54).

c. The high cockpit noise level in the YCH-47D (para 65).

d. The poor power management characteristics of the T55-L-712 engines at low power settings (para 47).

e. The poor visibility of the fore and aft hooks during tandem hook operations (para 70).

f. The insufficient volume of the interphone set (C6533/ARC) (para 68).

g. The lack of a mute capability in the interphone set (C6533/ARC) (para 69).

h. The high lateral breakout force on the cyclic beep trim button (para 28).

i. The lack of protection for the AC buss tie relay circuit breakers (para 56).

j. The unreliability of the radar altimeter during tandem external load operations (para 71).

k. The poor location of the emergency power lights (para 57).

l. The poor location of the engine starter lights (para 62).

m. The addition of the brake/steer and ramp isolation switches (para 58).

n. The removal of the utility and flight control hydraulic pressure gages from the cockpit (para 59).

o. The susceptibility of the longitudinal stick position indicator to impact damage (para 60).

p. The poor location of the maintenance panel (para 61).

q. The presence of collective creep at high power settings (para 30).

r. The tendency of the longitudinal speed trims and dash to program the fly position at light gross weights (para 44).

s. The pitch inputs to the AFCS by the manual adjustment of the VGI (para 74).

t. The color of the APU ON light (para 63).

SPECIFICATION COMPLIANCE

80. Within the scope of this test, the YCH-47D met the requirements of MIL-H-8501A as modified by the detailed specification with the following exceptions:

a. The longitudinal cyclic limit force (forward) failed to meet the requirements of MIL-H-8501A (para 3.2.6) as modified by the detailed specification in that the limit force exceeded 8 pounds by 2 pounds (25%) (para 26).

b. The mechanical characteristics of the thrust control failed to meet the requirements of MIL-H-8501A (para 3.4.2) as modified by the detailed specification in that creep was present at high power settings (para 30).

RECOMMENDATIONS

GENERAL

81. Correct the deficiency listed in para 78 prior to operational deployment.

82. Correct the shortcomings listed in para 79 as soon as practicable.

SPECIFIC

83. The AFCS section of the operator's manual should be modified to warn the pilot of the potentially hazardous pitch inputs that may be encountered after simulated dual AFCS failures. The following WARNING should be inserted following para 2-100:

WARNING

"Reengagement of the AFCS at an airspeed appreciably different from that of disengagement will result in extreme pitch inputs."

84. The AFCS altitude hold section of the operator's manual should contain a note to the pilot that the altitude hold mode of the AFCS does not provide engine or transmission protection. The following NOTE should be inserted after paragraph 2-105:

NOTE

"The altitude hold feature of the AFCS does not provide engine or transmission protection and may produce engine overtorques or overtemps under extreme operating conditions."

APPENDIX A. REFERENCES

1. Letter, AVRADCOM, DRDAV-DI, 25 June 1979 with revision 1, dated 5 October 1979, subject: Preliminary Airworthiness Evaluation of the YCH-47D.

2. Document, Boeing Vertol Company, No. 145-PJ-7103, *Prime Item Development Specification for the Model YCH-47D Helicopter*, 20 June 1975, with revision D.

3. Military Specification, MIL-L-8501A, *Helicopter Flying and Ground Handling Qualities; General Requirement For*, 7 September 1961, with amendment, dated 3 April 1962.

4. Technical Manual, DEPTM 55-1520-240-10, *Operator's Manual, Army Model YCH-47D Helicopter*, 3 December 1979.

5. Letter, AVRADCOM, DRDAV-DI, 7 September 1979 with revision 1, dated 8 November 1979, subject: Airworthiness Release for Conduct of Preliminary Airworthiness Evaluation of the YCH-47D Helicopter, USAAVRADCOM/USAAEFA Project No. 79-06.

6. Flight Test Manual, Naval Air Test Center, FTM No. 102, *Helicopter Performance Testing*, 28 June 1968.

7. Flight Test Manual, Naval Air Test Center, FTM No. 101, *Helicopter Stability and Control*, 10 June 1968.

8. Final Report, USAAEFA, Project No. 77-31, *Preliminary Airworthiness Evaluation CH-47C with Fiberglass Rotor Blades (with T55-L-712 Engines)*, April 1979.

9. Document, Lycoming Company, No. 124.53, *Prime Item Development Specification for the T55-L-712 Engine*, 19 November 1975, with Addendum, 15 June 1975.

10. Letter Report, USAAEFA, Project No. 77-29, *Airworthiness and Flight Characteristics Evaluation, CH-47C Helicopter with T55-L-712 Engines*, 16 March 1978.

11. Letter Report, Acoustical Research Branch, Engineering Research Laboratory, US Army Human Engineering Laboratories, No. 95, *Interior Noise Evaluation of the CH-47C Helicopter*, January 1969.

12. Document, Boeing Computer Service, No. 80092-8CI, *Specification for the CH-47 Real Time Performance Program (H47PWR)*, August 1978.

APPENDIX B. AIRCRAFT DESCRIPTION

GENERAL

1. The YCH-47D is a twin-turbine engine, tandem rotor helicopter (photo 1) designed for internal and external cargo transport during visual and instrument, day and night operations. It is powered by two T55-L-712 shaft-turbine engines housed in pylons mounted on the aft fuselage. The engines drive tandem, three-bladed, fully-articulated, counterrotating rotors. The drive train system consists of two engine transmissions, a combining transmission, and a forward and aft transmission. The combining transmission receives power from the engine transmissions and drives the forward transmission through drive shafting housed in a tunnel along the top of the fuselage. The aft transmission is driven by a drive shaft running from the aft section of the combining transmission. A gas turbine auxiliary power unit mounted in the aft pylon, drives a hydraulic pump and 20 KVA generator to provide power to the aircraft systems when the rotors are stationary. Fuel is carried in six tanks mounted in pods on each side of the fuselage. The helicopter is equipped with four nonretractable landing gears with steering provided by the right aft gear. Entrance to the helicopter is provided through a door located on the forward right side of the cargo compartment or through a hydraulically operated cargo ramp located at the rear of the cargo compartment. The helicopter is equipped with standard tandem rotor cockpit controls (photos 2 through 4) and an advanced flight control system (AFCS) described below. The allowable center of gravity (cg) envelope is shown in figure 1 with the ballast configuration shown in photo 5.

2. The general helicopter arrangement and dimensions are shown in Boeing Vertol (BV) drawing 145 x 1001 inclosed as figures 2 and 3. Component location is shown in BV drawing 145 x 2001 inclosed as figures 4 through 7.

FLIGHT CONTROLS

General

3. The irreversible, electrohydraulic flight control system is powered by two independent hydraulic boost systems, each operating at 3000 psi pressure. Control inputs from the cockpit are transmitted through mechanical linkage to the integrated lower control actuator (ILCA) which then transmits individual axis-oriented control motions to the mechanical mixing units. The mixed outputs are then transmitted through a series of push-pull tubes to the upper dual-boost actuators attached to the forward and aft swashplates.

Advanced Flight Control System (AFCS)

General:

4. Automatic inputs from the AFCS enter the flight control system by two means:

a. In series, between the cockpit controls and the rotors, through the ILCA and the differential airspeed hold (DASH). These signals do not move the cockpit controls.

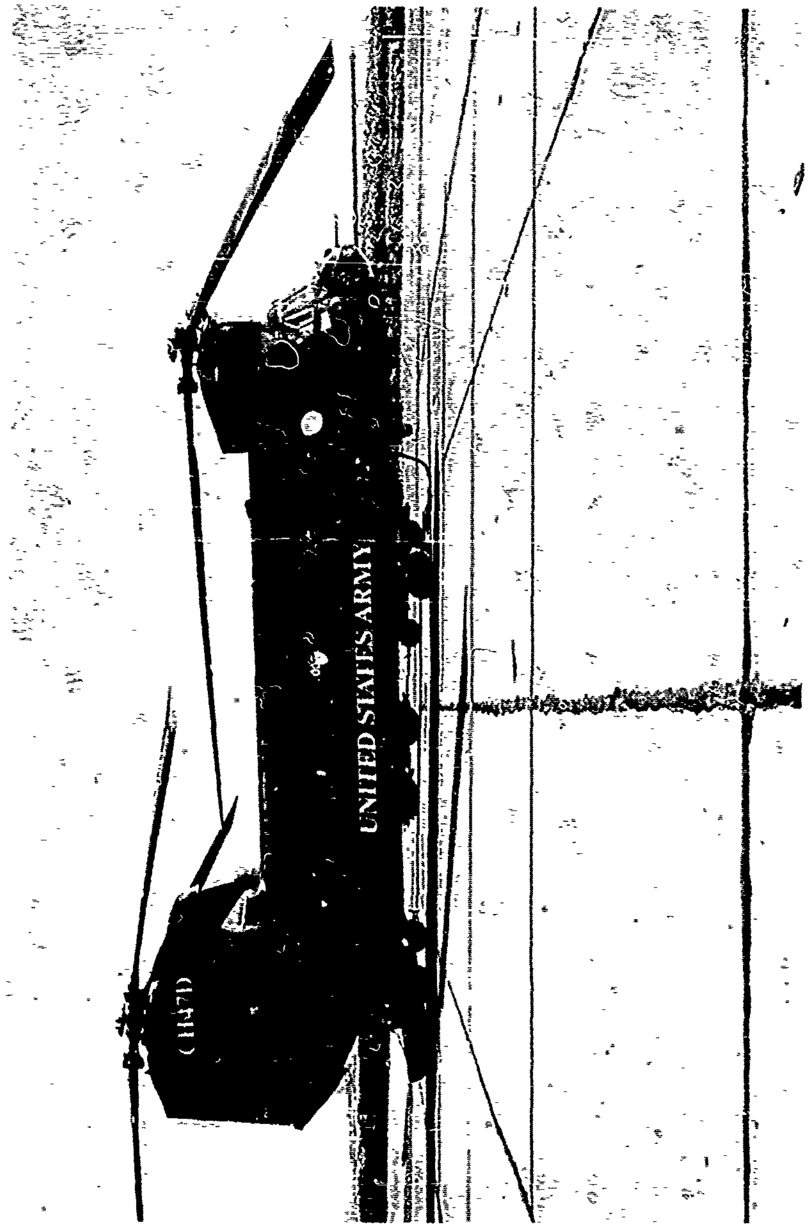


Photo 1. YCH-47D Helicopter

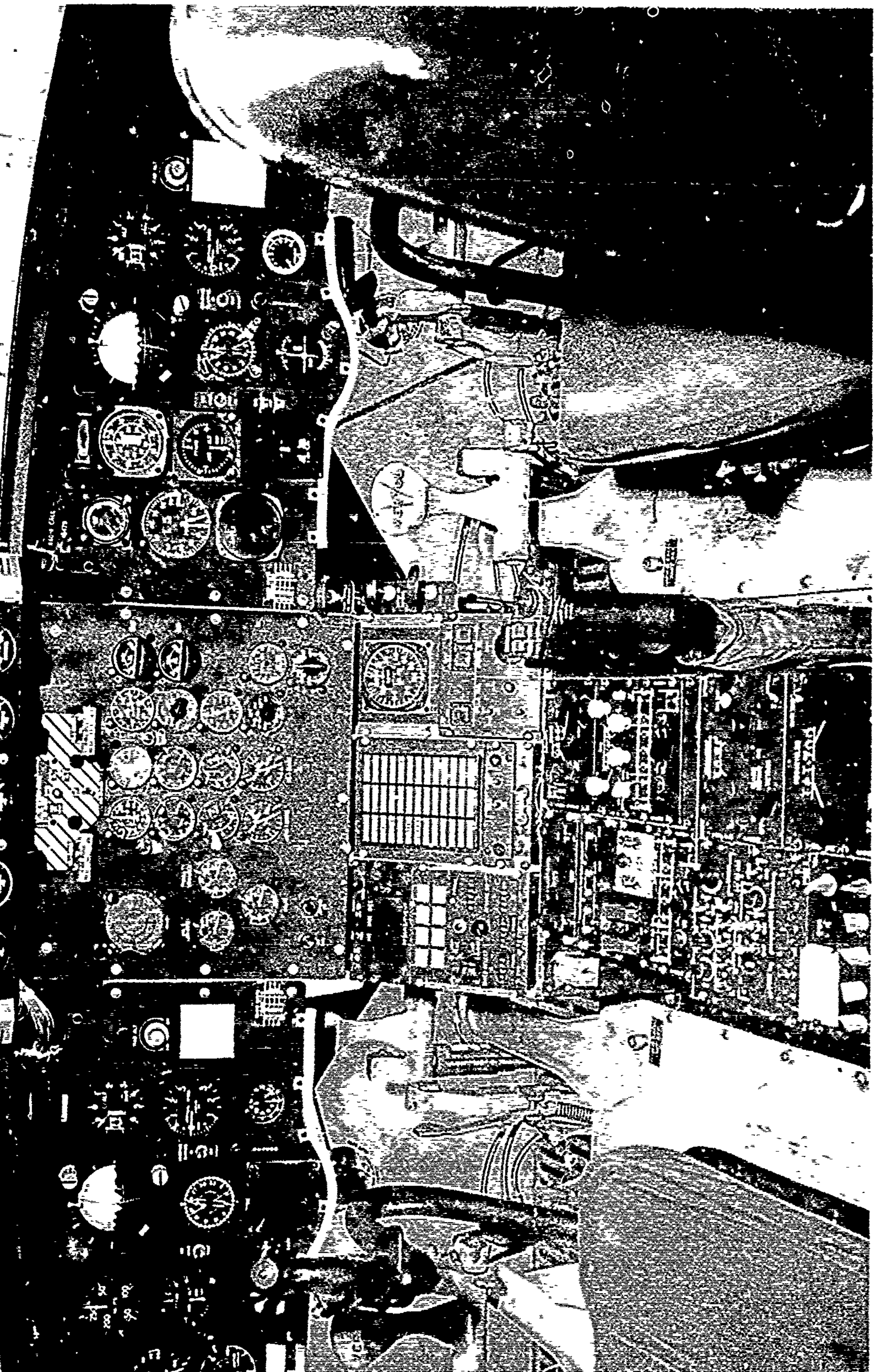


Photo 2. YCH-47D Cockpit

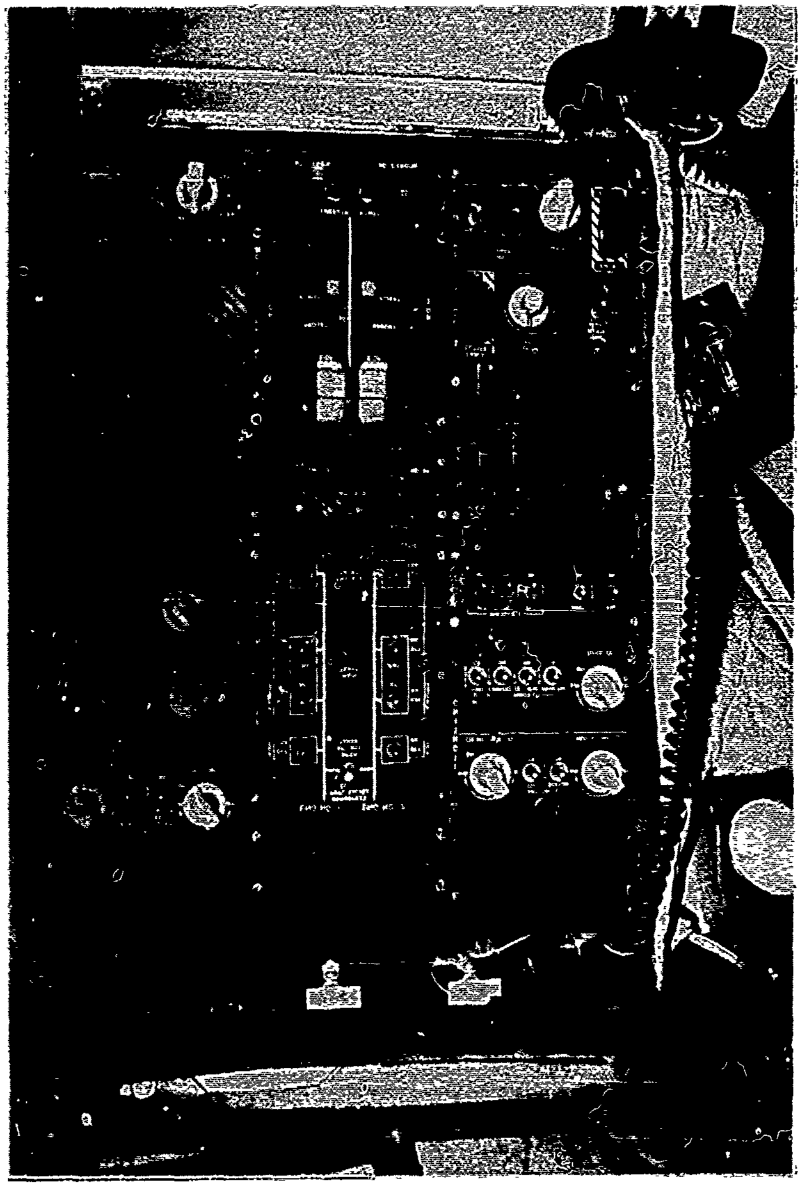


Photo 3. YCH 47D Overhead Console

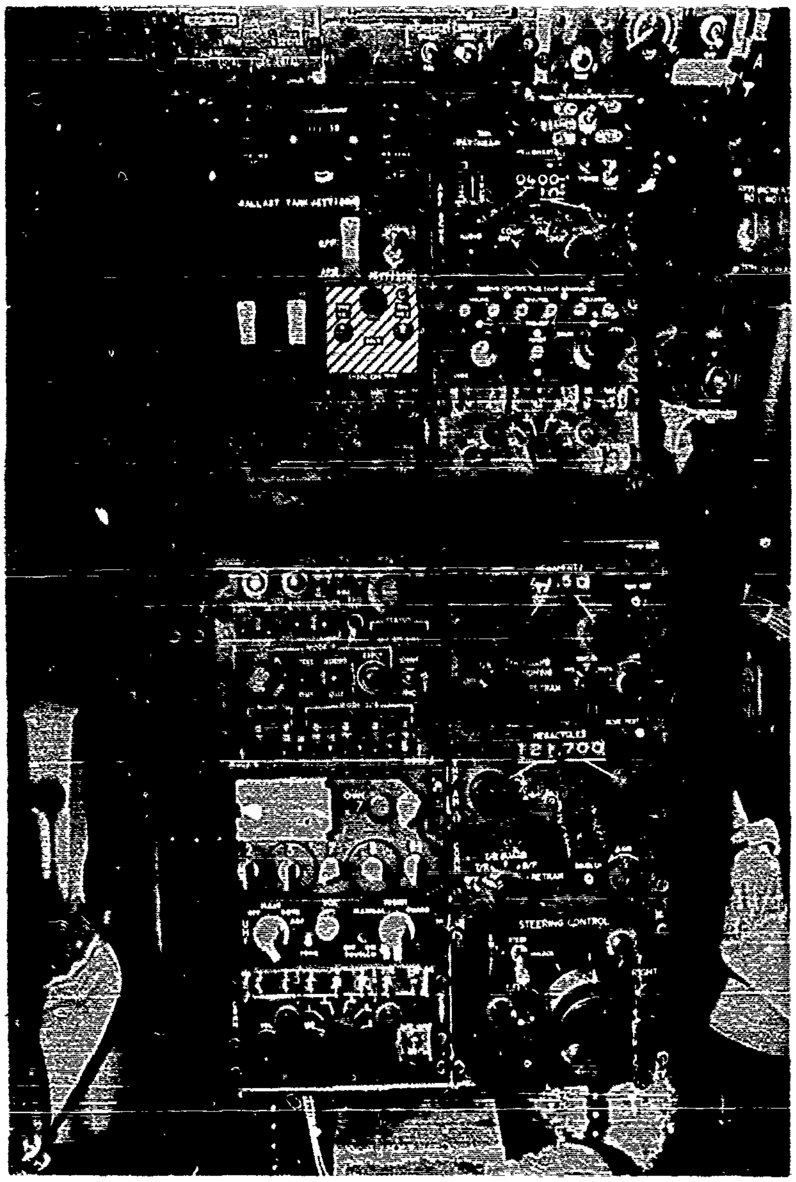


Photo 4. YCH-47D Lower Console

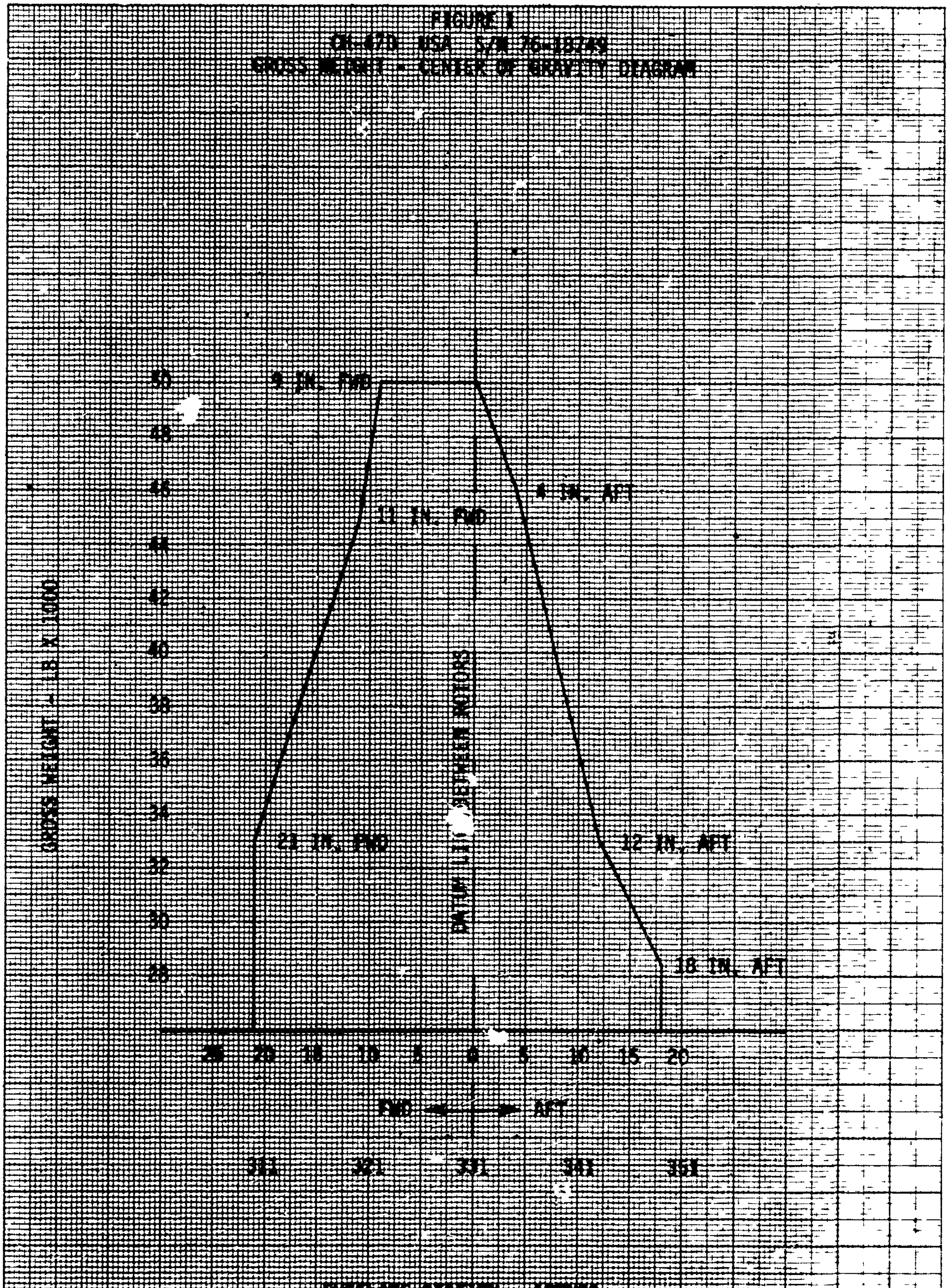


FIGURE 1
CH-47D USA S/N 76-18749
GROSS WEIGHT - CENTER OF GRAVITY DIAGRAM
GROSS WEIGHT - LB X 1000
50
48
46
44
42
40
38
36
34
32
30
28
9 IN. FWD
11 IN. FWD
21 IN. FWD
4 IN. AFT
12 IN. AFT
18 IN. AFT
25
20
15
10
5
0
5
10
15
20
FWD
AFT
311
321
331
341
351
FUSELAGE STATION - INCHES

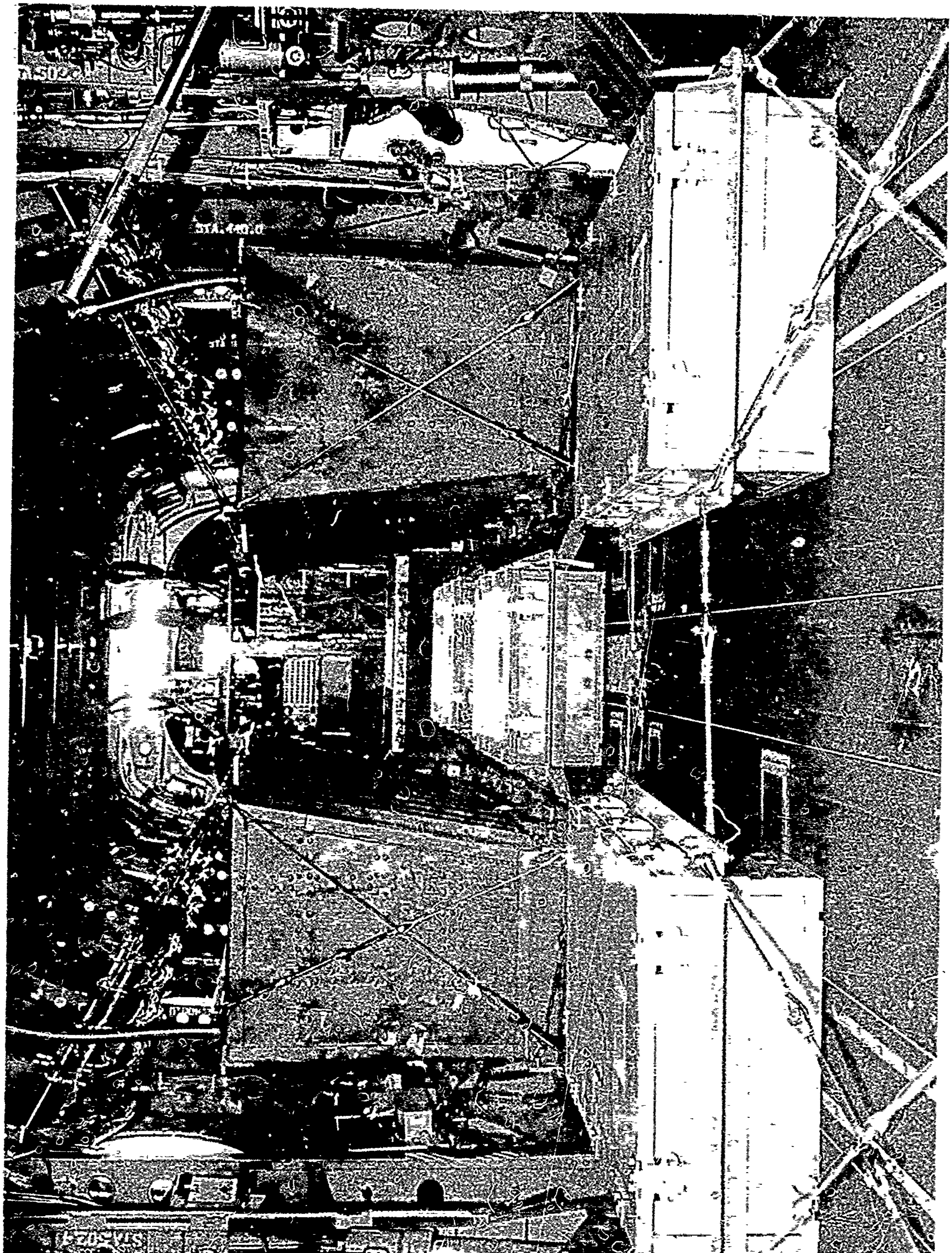
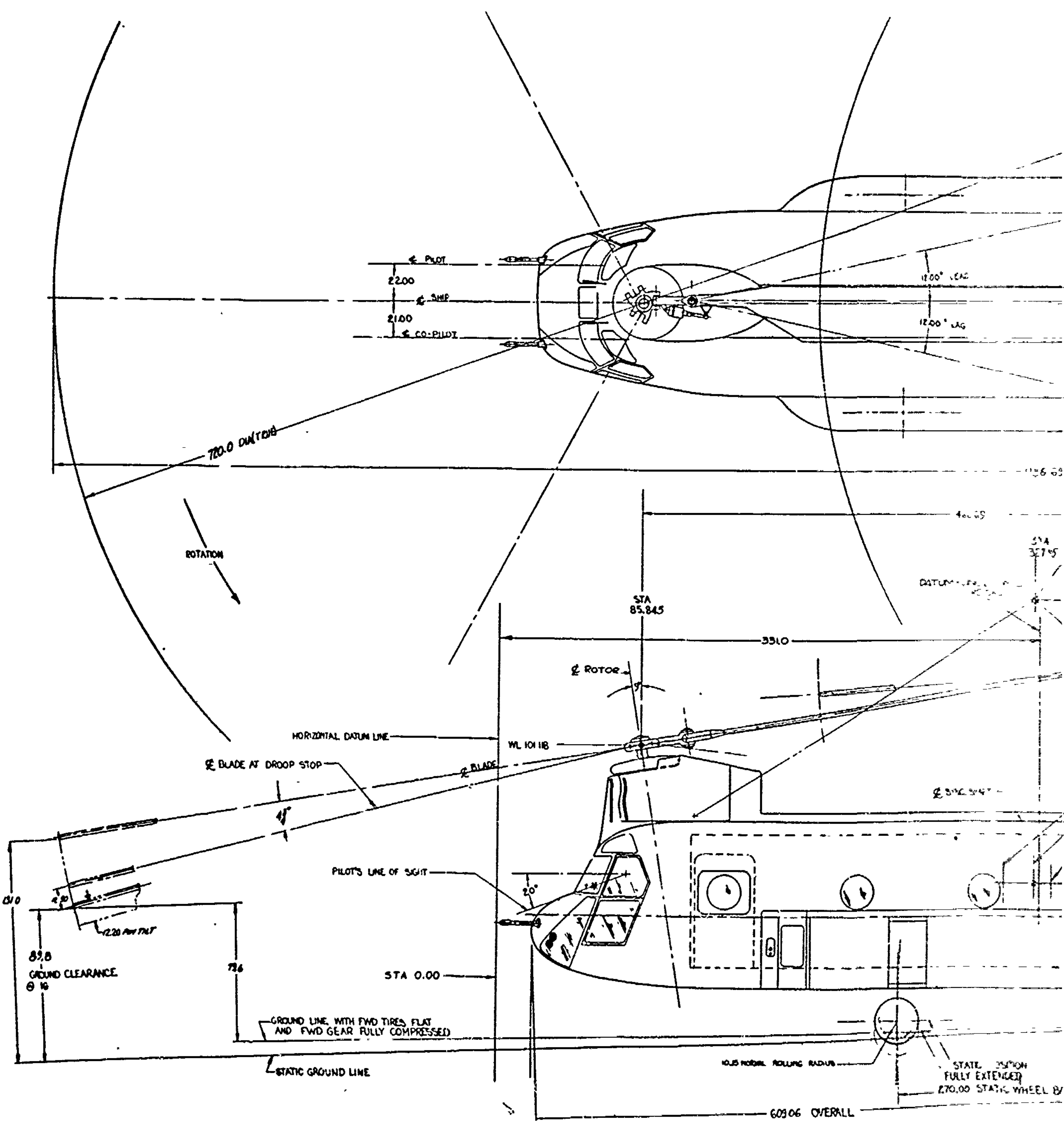


Photo 5. Ballast Configuration



℄ PILOT
22.00
℄ SHIP
21.00
℄ CO-PILOT
720.0 DIA ROTOR
ROTATION
12.00° LEAD
12.00° LAG
STA 85.845
331.0
℄ ROTOR
HORIZONTAL DATUM LINE
WL 101.118
℄ BLADE AT DROOP STOP
℄ BLADE
PILOT'S LINE OF SIGHT
20°
131.0
89.8
GROUND CLEARANCE
STA 0.00
GROUND LINE, WITH FWD TIRES FLAT AND FWD GEAR FULLY COMPRESSED
STATIC GROUND LINE
FULLY EXTENDED
270.00 STATIC WHEEL BA
609.06 OVERALL

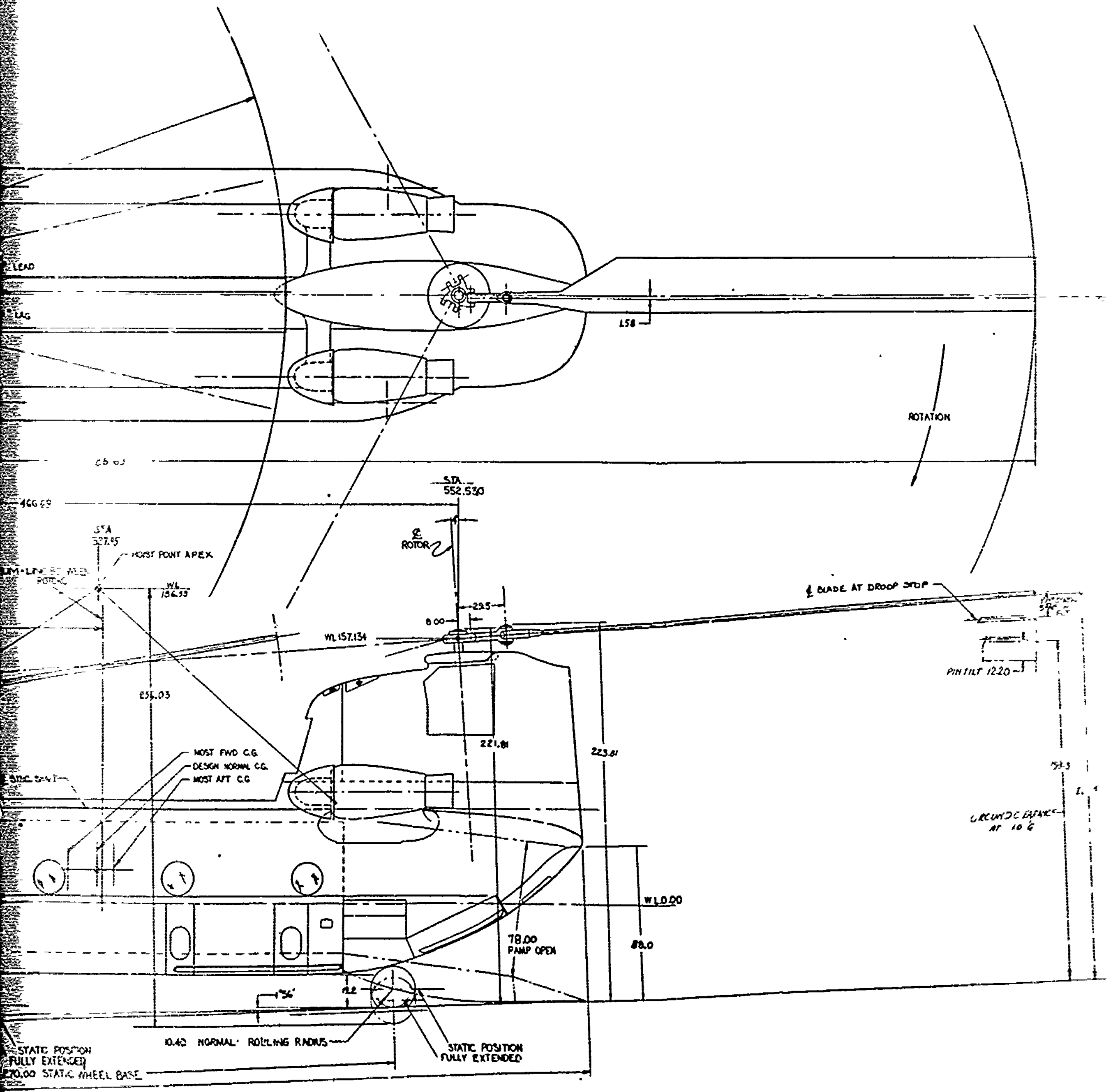


Figure 2. YCH-47D Dimensions

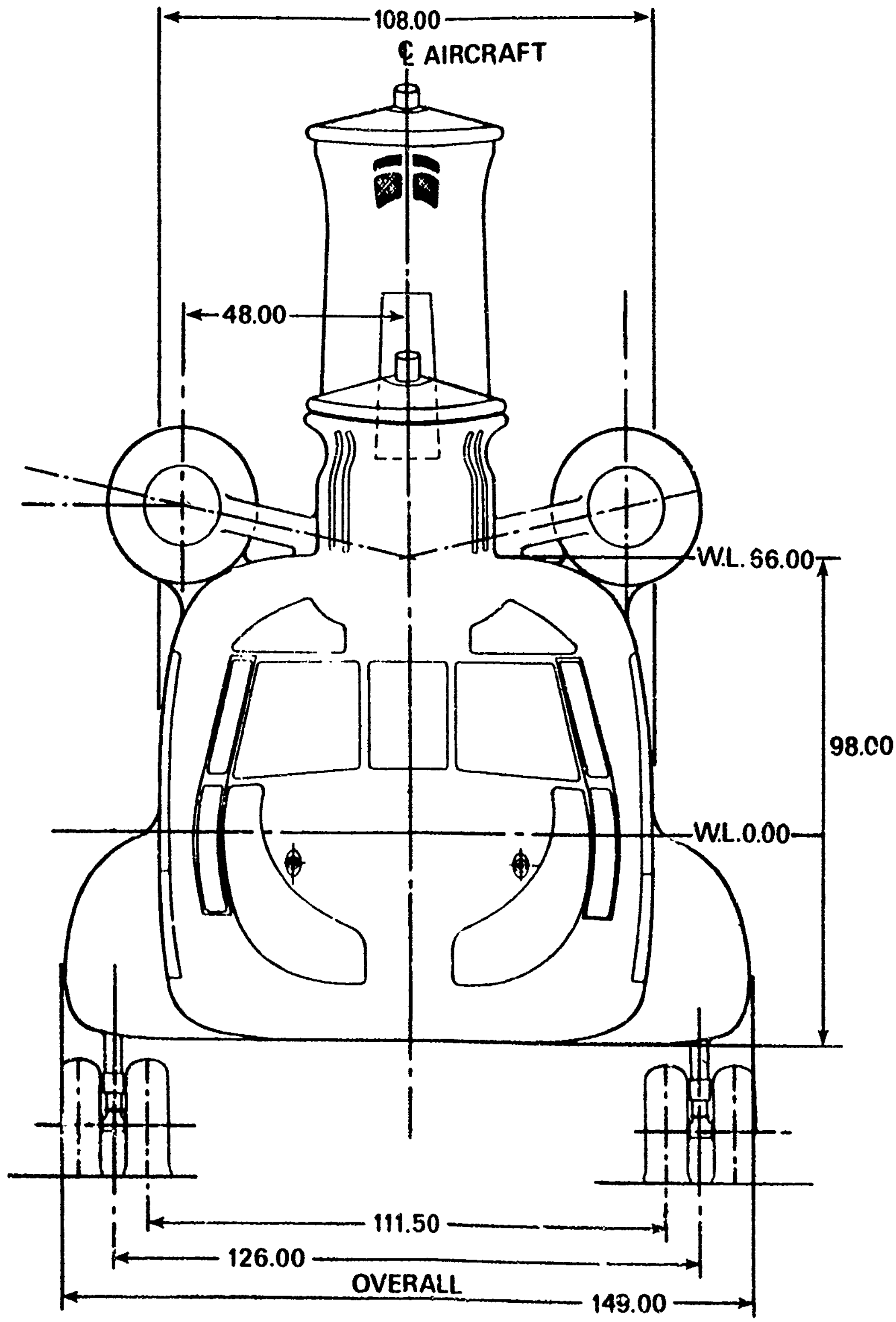


Figure 3. YCH-47D Dimensions

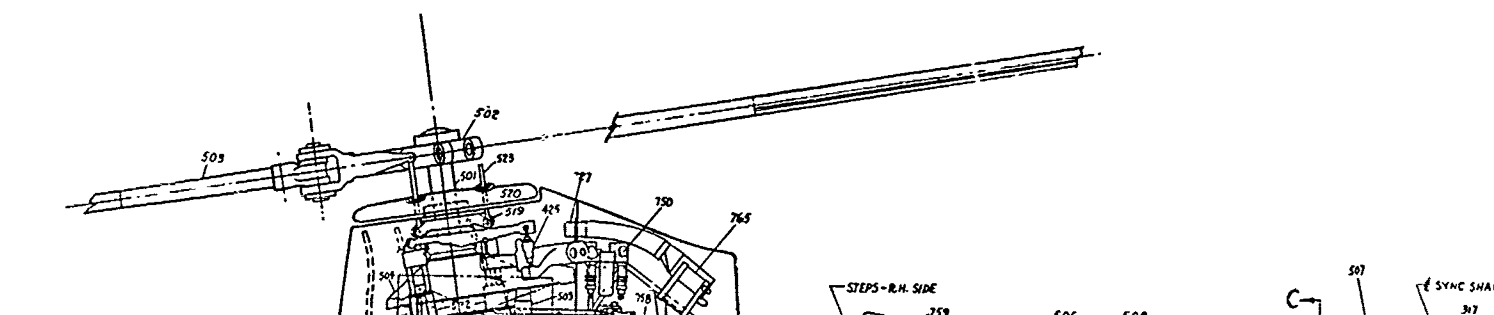
SPECIFICATIONS -- YCH-47D HELICOPTERS

	YCH-47D
BLADE AREA - EACH	80 SQ FT
BLADE AREA - TOTAL	480 SQ FT
ROTOR DISC AREA - EACH	2,827 SQ FT
ROTOR DISC AREA - TOTAL	5,655 SQ FT
AIR FOIL - ROOT (INBD TO 85%)	VR7
AIR FOIL - TIP	VR8
AERODYNAMIC CHORD LENGTH - ROOT & TIP	32.0 IN
PITCH AXIS - % OF CHORD	25%
BLADE PITCH RANGE - AFT	-21.39 TO +39.85
BLADE PITCH RANGE - FWD	-21.39 TO +39.85
BLADE TWIST FROM ℄ OF ROTOR TO BLADE TIP	12 degrees
CONING STOP ANGLE	30 degrees
COLLECTIVE PITCH (THRUST)	1 degree-18 degrees
ROTOR DISC LOADING (50,000 GROSS WEIGHT)	8.84 LB/FT^2
SOLIDITY RATIO	.0849
NORMAL ROTOR RPM	225
ROTOR RPM - MAX. AUTOROTATION	244
TRANSMISSION RATING TWIN ENGINE	7500 HP @ 225 RPM
TRANSMISSION RATING SINGLE ENGINE	4600 HP @ 225 RPM
GEAR RATIO - ENGINE TO ROTOR	66.96 TO 1
TIP SPEED - NORMAL	707 FPS
WEIGHT EMPTY	22,784 LBS
DESIGN USEFUL LOAD	10,216 LBS
DESIGN GROSS WEIGHT	33,000 LBS
ENGINE MODEL DESIGNATION (2)	LYC T-55 - L-712
T.O. RATED SHP @ 15066 RPM	3704 . SEA LEVEL
MAX CONTINUOUS RATED SHP @ 15066 RPM	2987 . . STD DAY
FWD TIRES	8.50-10 III 10 PR
AFT TIRES	8.50-10 III 10 PR
DESIGN NORMAL C.G. LOCATION	3.1 IN FWD
MOST FWD C.G.LOCATION (33,000 lbs GROSS WGT)	21.3 IN AFT
MOST AFT C.G. LOCATION (33,000 lbs GROSS WGT)	7.0 IN AFT
MANUFACTURER MODEL NO.	YCH-47D
CARGO HOOK LOCATIONS	STA 249, 331 & 409
CARGO COMPARTMENT - HEIGHT	78 IN MIN
CARGO COMPARTMENT - WIDTH	90 IN MIN

NOTES:

[1] ALL ABOVE C.G. LOCATIONS ARE TAKEN FROM THE DATUM-LINE BETWEEM ROTORS – STA 331.0

[2] REF 145X0001 HELICOPTER ASSY
145X2001 INBOARD PROFILE



STEPS-R.H. SIDE
STA 21.5
STA 95
STA 120
STA 160
STA 200
STA 280
STA 320

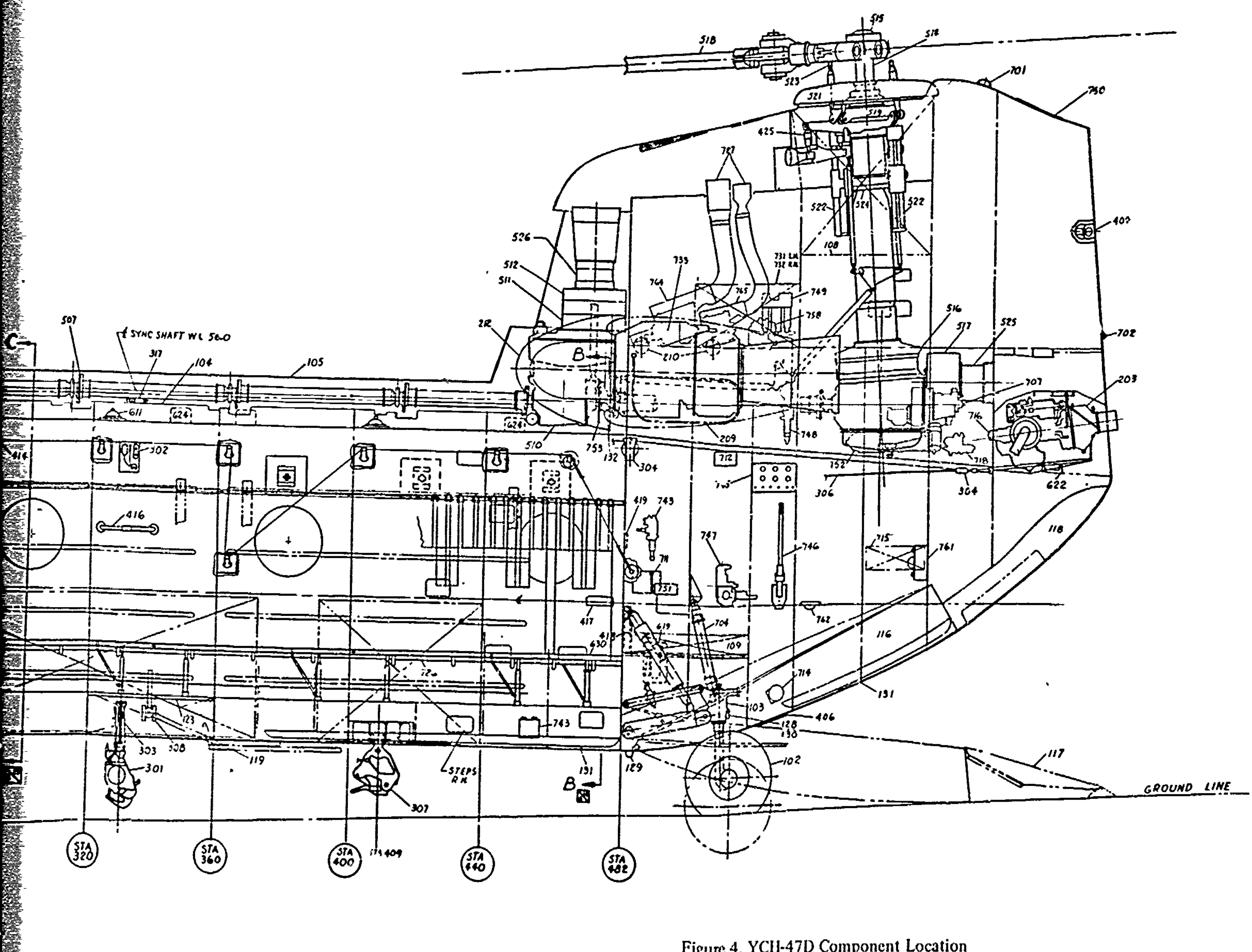


Figure 4. YCH-47D Component Location

2

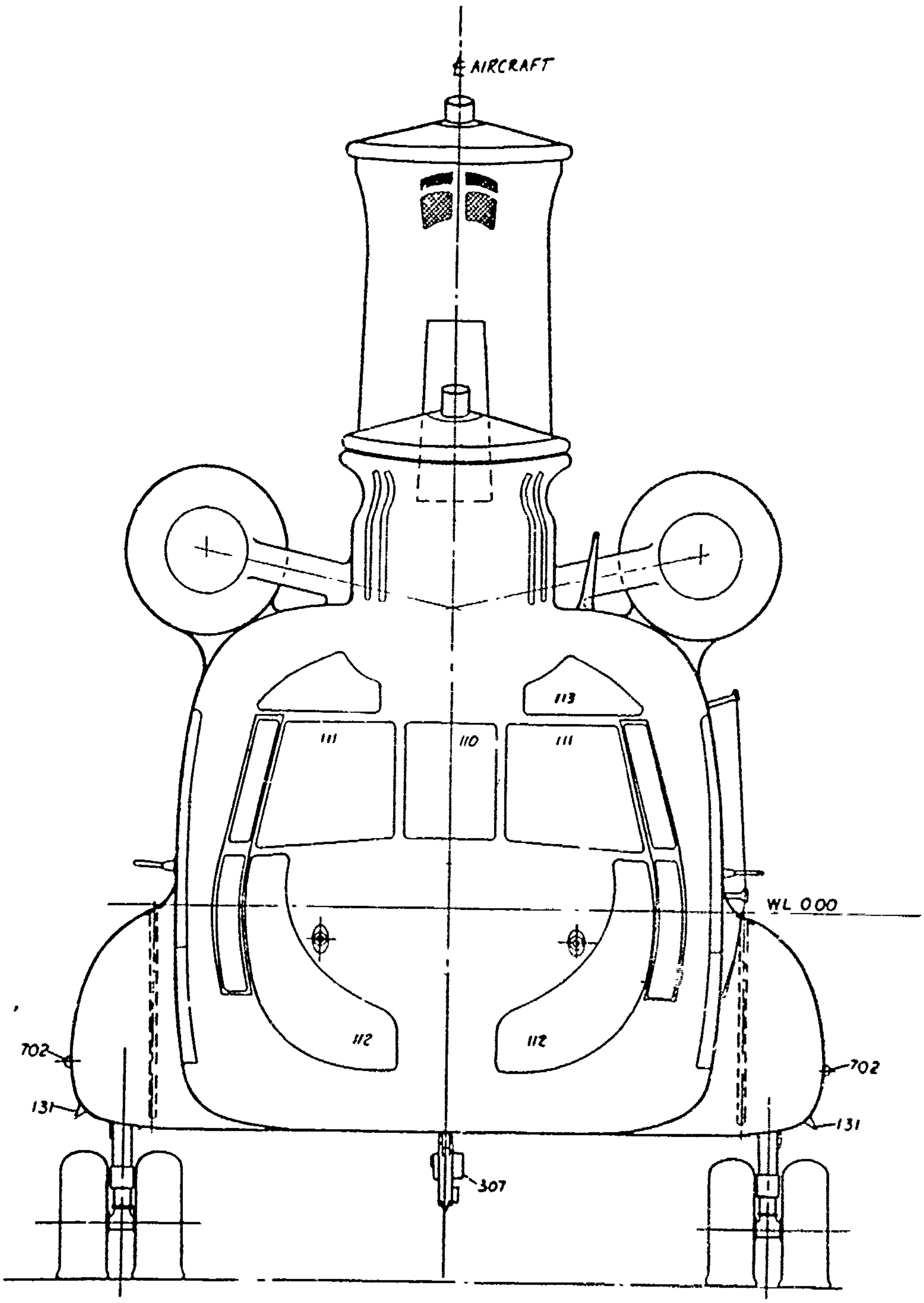
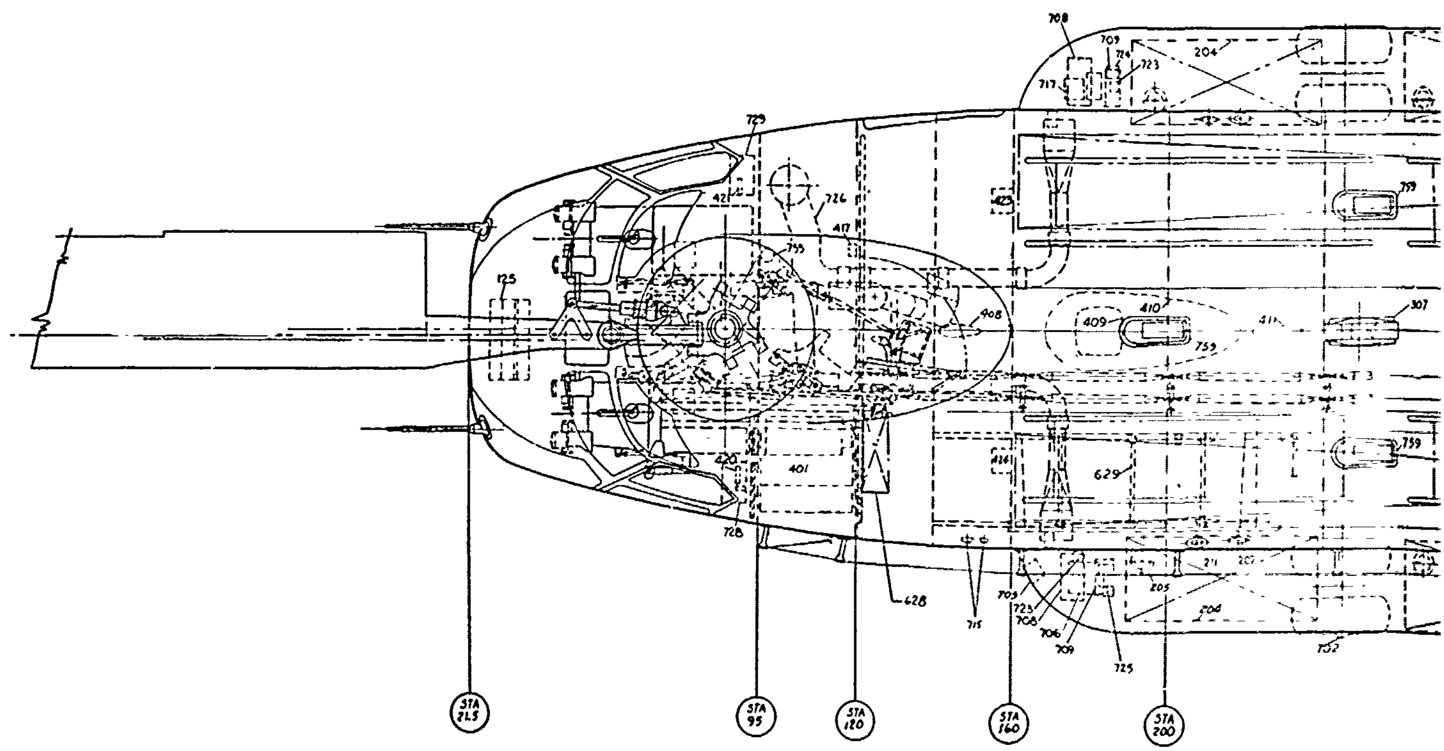


Figure 5. YCH-47D Component Location


708
709
723
204
717
729
42
726
417
423
759
125
755
408
410
409
307
629
420
401
424
728
628
715
705
706
205
702
STA 215
STA 95
STA 120
STA 160
STA 200

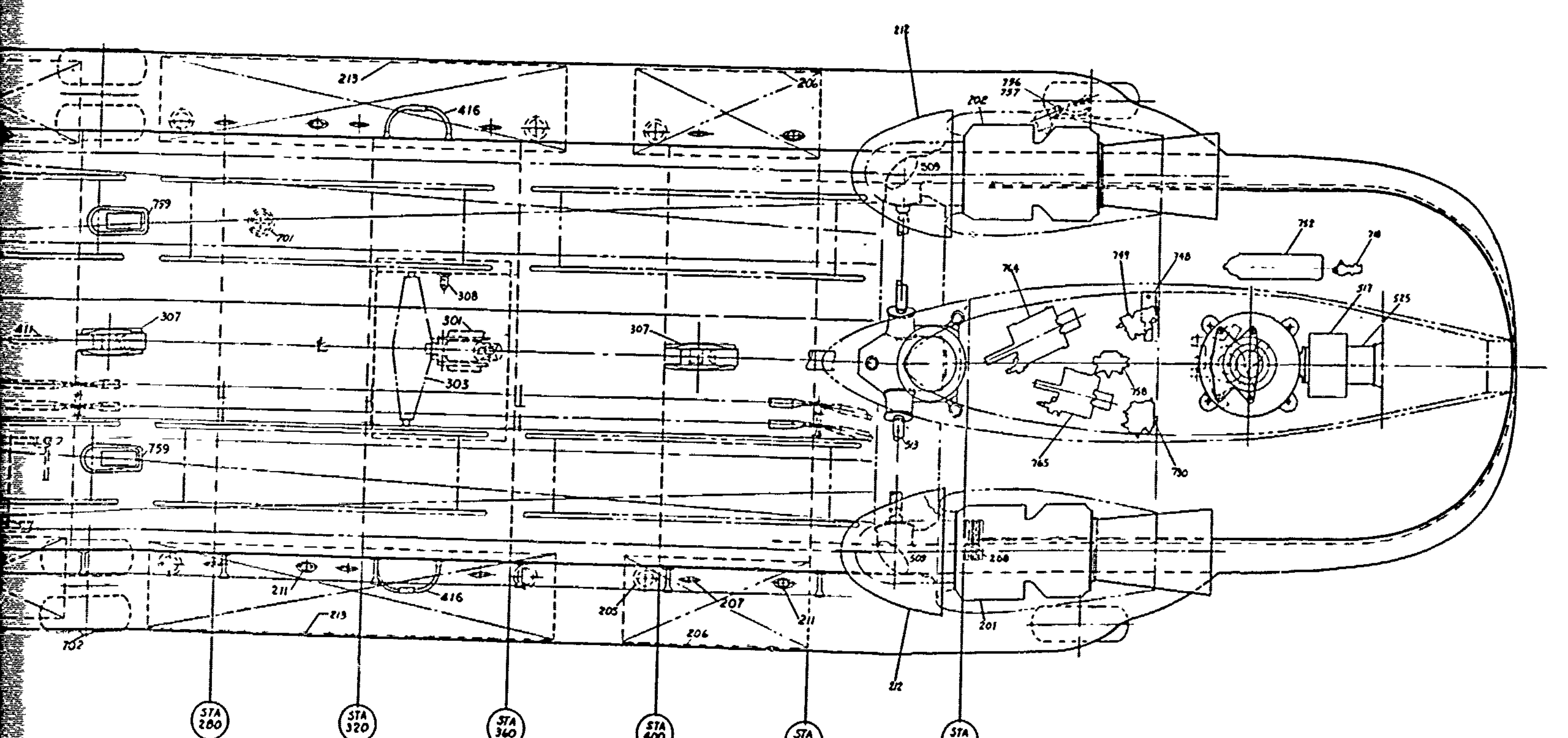
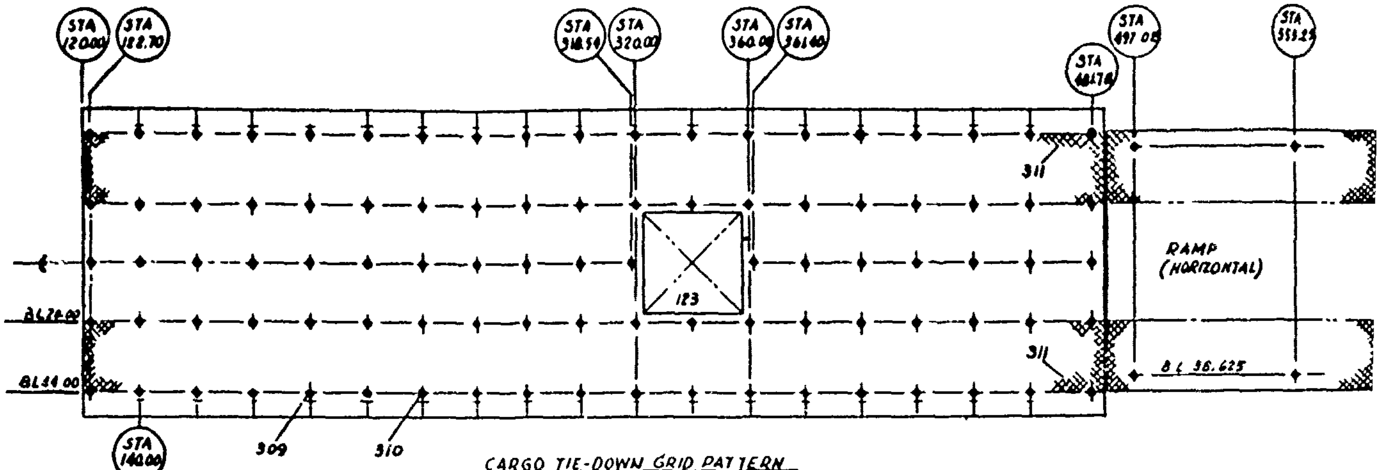
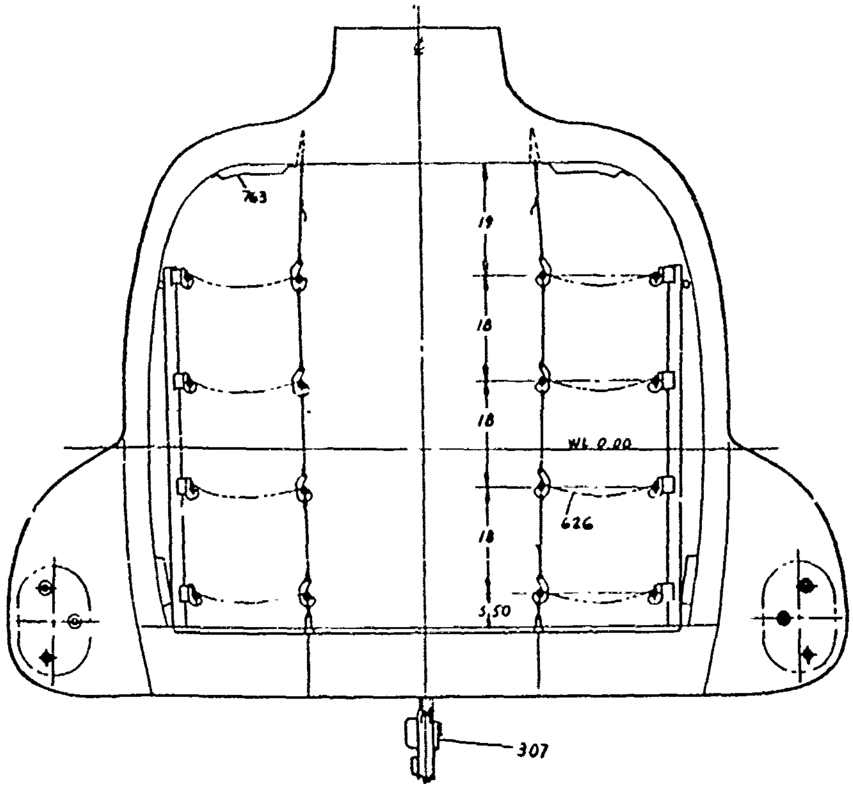


Figure 6. YCH-47D Component Location

2



CARGO TIE-DOWN GRID PATTERN
SCALE 1/20



SECTION B-B

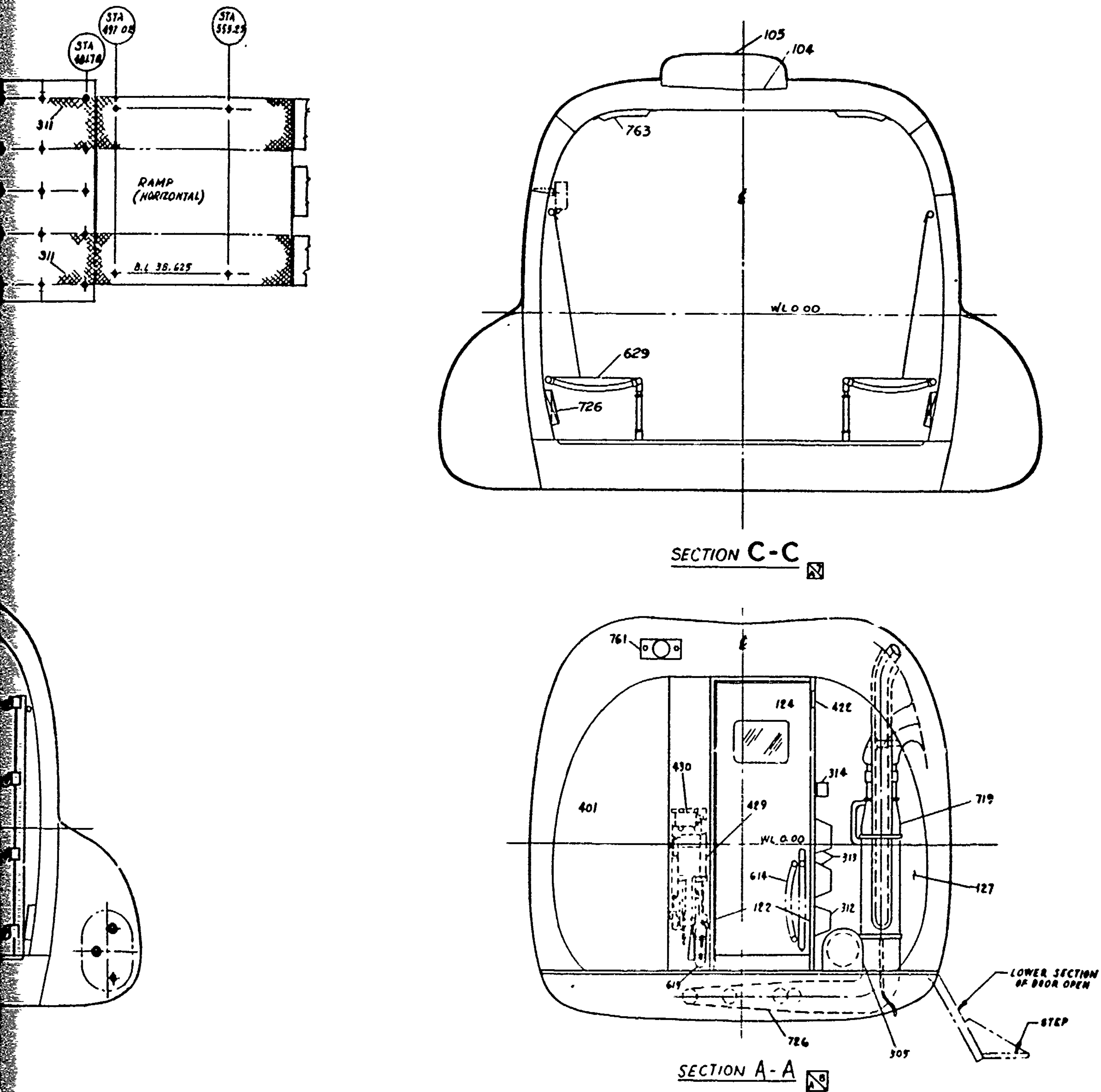


Figure 7. YCH-47D Component Location

(See Figures 4 through 7)

AIRFRAME AND LANDING GEAR

101	Forward landing gear assembly
102	Aft landing gear assembly
103	Power steering unit
104	Drive shaft tunnel
105	Tunnel covers
106	Split cabin door - R.H.
107	Forward pylon work platform - L and R
108	Aft pylon work platform - L and R
109	Engine work platform - L and R
110	Heated center windshield, glass-faced
111	Heated side windshield, all glass - L and R
112	Forward vision transparent panel - L and R
113	Overhead vision transparent panel, tinted - L and R
114	Pilots emergency exits doors - L and R
115	Forward pylon spoilers - L and R
116	Ramp
117	Auxiliary ramp (3)
118	Jettisonable cargo door
119	Outer rescue door
120	Cabin emergency exit - L and R
121	Forward transmission acoustic treatment
122	Passageway acoustical treatment
123	Inner rescue door
124	Cockpit door - station 120 - acoustical
125	Self-tuning vibration absorber (3)
126	Hard panel station 95 - acoustical
127	Hard panel station 120 - acoustical
128	Mooring fitting
129	Jacking point
130	Towing fitting
131	Strakes
132	Hoist fitting

PROPULSION AND FUEL SYSTEM

201	Left engine installation
202	Right engine installation
203	Auxiliary power unit
204	Self-sealing fuel cell - fwd aux. (2)
205	Fuel booster pump (8)
206	Self-sealing fuel cell - aft aux. (2)
207	Fuel quantity measuring unit (10)
208	Engine cooling air inlet
209	Engine fire detection unit
210	Engine fire extinguisher
211	Gravity fill cap (6)
212	Engine air inlet screen (2)
213	Self-sealing fuel cell - main (2)

CARGO HANDLING SYSTEM

301	Cargo hook
302	Cargo hook operator panel
303	Fixed point cargo hook beam
304	Parachute static line retriever unit
305	Hoist/Cargo winch
306	Parachute anchor line
307	Cargo hook, externally mounted (2)
308	Manual release control, cargo hook
309	5,000 pound tie down fittings
310	10,000 pound tie down fittings
311	Vehicle treadway
312	Hoist operators harness stowage
313	Hook and tackle stowage
314	Winch control valve
315	Parachute anchor line stowage container
316	Parachute anchor line - fwd attachment
317	Cargo hook release valve

FLIGHT CONTROLS AND AVIONICS

401	Avionics system compartment
402	Magnetic brake (2)
403	FM communications antenna
404	Radar warning antenna (5)
405	Radar altimeter antenna (2)
406	I.F.F. antenna (2)
407	FM homing antenna
408	UHF/VHF antenna
409	ADF loop antenna
410	ADF sense antenna
411	Marker beacon antenna
412	Damper (4)
413	Glide slope antenna
414	H.F. antenna
415	L.V.D. transducer (3)
416	VOR antenna
417	Crew chief ICS
418	Crew chief cord assembly
419	Crew chief ICS jack
420	Copilot's ICS jack
421	Pilot's ICS jack
422	Troop commander's ICS jack
423	Right hand gunner's ICS
424	Left hand gunner's ICS
425	Long cyclic trim actuator (2)
426	Cyclic control stick
427	Yaw control pedals
428	Collective/Power control lever
429	Spring assemblies, artificial feel (3)
430	ATS actuators (2)
431	Integrated lower control actuator SAS and boost (4)
432	Dash actuator

DYNAMIC SYSTEM

501	Forward rotor shaft
502	Forward rotor hub
503	Forward rotor blades (3)
504	Forward rotor transmission
505	Forward rotor transmission oil cooler and fan
506	Sync shaft
507	Sync shaft couplings
508	Sync shaft supports
509	Engine transmission (2)
510	Combining transmission
511	Combining transmission oil cooler
512	Engine transmission oil cooler (2)
513	Cross shaft (2)
514	Aft rotor shaft
515	Aft rotor hub
516	Aft rotor transmission
517	Aft rotor transmission oil cooler
518	Aft rotor blades (3)
519	Swashplate (2)
520	Forward rainshield
521	Aft rainshield
522	Dual boost actuators (4)
523	Pitch link (6)
524	Thrust bearing housing
525	Aft oil cooler blower
526	Combining transmission oil cooler blower

CREW AND PASSENGER STATIONS AND EQUIPMENT

601	Pilot
602	Copilot
603	Pilot seats (2)
604	Engine fire control panel
605	Instrument panels - left, right, and center
606	Center console
607	Overhead panel
608	Cockpit ash receiver
609	Cockpit dome light
610	Cockpit utility light
611	Cabin dome lights (4)
612	Cockpit first aid kit
613	Cabin first aid kits
614	Troop commander - crew shief seat and lap belt
615	Engine condition panel
616	Pilot and copilot lap belt
617	Pilot and copilot shoulder harness
618	Cockpit hand fire extinguisher
619	Cabin hand fire extinguisher (2)
620	Windshield wiper (2)
621	Emergency exit sign
622	Emergency exit lights (3)
623	Standby compass

624 Litter support strap stowage (16 places)
625 Litter pole upper support studs
626 Litter position - 4 high
627 Pitot tube (2)
628 Litter pole stowage area
629 3 man troop seat (14) with back and seat belt
630 1 man troop seat with back and seat belt (3)

HYDRAULIC PNEUMATIC - ELECTRICAL AND ENVIRONMENTAL CONTROL SYSTEMS

701 Flasher/Anti-collision light
702 Navigation light (3)
703 Adjustable search and landing light (2)
704 Ramp hydraulic actuator (2)
705 External power receptacle
706 Battery
707 Generator (2)
708 Rectifier (2)
709 Generator control box (3)
710 SAS ports
711 Ramp and door control panel
712 APU control panel
713 Battery relay
714 Hydraulic motor - cargo door
715 External servicing connectors (2)
716 Hydraulic pump motor - APU
717 Remote engine speed control (2)
718 APU start module
719 Heater
720 Lower cockpit window defog duct
721 Foot warmer duct
722 Side lower cockpit window defog duct
723 Engine trim relay (2)
724 Emergency engine trim relay
725 Battery charger
726 Cabin heating and vent distribution duct
727 Cooling fan (3) - hydraulic system
728 AC and DC distribution box number 1
729 AC and DC distribution box number 2
730 Pressure control module
731 Hydraulic module - aft flight control, access panel
732 Hydraulic module - utility system, access panel
733 Engine starter motor (2)
743 Swivel lock power steering module
744 Brake master cylinder
745 Hydraulic maintenance panel
746 Hydraulic hand pump
747 Hydraulic filler
748 Return control module, utility
749 Hydraulic power package - flight control system #2
750 Hydraulic power package - flight control system #1
751 Ramp control
752 Accumulator - APU start
753 Rotor brake (provision)

754	Parking brake valve
755	Accumulator - brake system
756	Power steering actuator
757	Swivel lock and centering cam (2)
758	Power transfer unit (2)
759	Formation light fwd (3)
760	Formation light aft (2)
761	Troop alarm
762	Flux valve
763	Lower control pressure module (2)
764	Reservoir cooler - utility
765	Reservoir cooler - flight control (2)

b. In parallel, with the collective controls through a collective control drive actuator (CCDA). These signals move the cockpit collective controls.

5. The AFCS provides the following modifications and additions to the stability augmentation system installed in earlier model CH-47 helicopters:

a. Continuous pitch attitude and, in the long term, airspeed hold referenced to the longitudinal control position throughout the flight envelope.

b. Long term bank angle and heading hold in level flight and bank angle hold about any stabilized bank angle in turning flight.

c. A stable longitudinal control gradient from maximum rearward to maximum forward flight speeds.

d. Vernier beep trim of bank angle and airspeed.

e. Radar and barometric altitude hold.

f. Coupled heading selected through the RMI bug error.

g. Cockpit control position transducers (control stick pick-offs) in the longitudinal, lateral, and directional control systems to improve maneuverability.

h. The mechanical detent switches on the lateral and directional controls have been replaced by electronic signals derived from control position signals supplied to the AFCS.

i. Automatic longitudinal cyclic trim positioning to the ground mode when both aft wheels are on the ground.

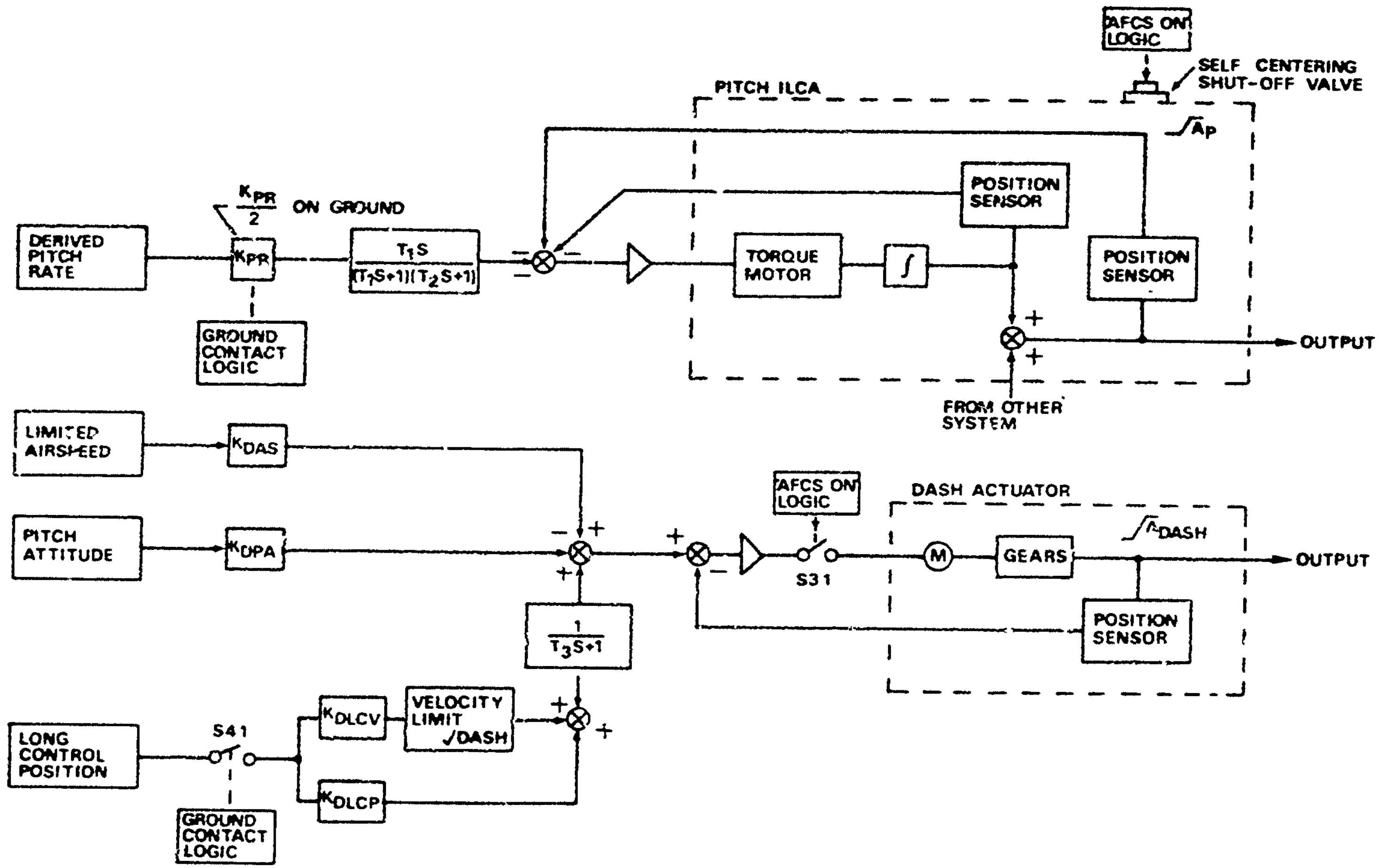
Longitudinal Control:

6. As shown in figure 8, pitch rate damping is provided by feeding derived pitch rate into the extensible link of the longitudinal ILCA. The derived pitch rate is obtained by electronically differentiating the vertical gyro pitch attitude signal and using it along with yaw rate and roll attitude to calculate the body axis pitch rate. The signal is conditioned by a lag to filter noise and a washout to prevent saturation during turns.

7. By summation of aircraft pitch attitude, airspeed, and longitudinal control position, the DASH system actuator provides pitch attitude and airspeed hold as well as a stable gradient of longitudinal control position versus trim airspeed. Since neither pitch attitude nor airspeed are synchronized, their high gain settings would, if not otherwise modified, require very large longitudinal control displacements to oppose their effects. The incorporation of a longitudinal control position transducer (stick pick-off) acts as a pseudo synchronizer and cancels out most of the airspeed and attitude signal so that the trim control travel over the allowable operating speed range is approximately 2-1/2 inches.

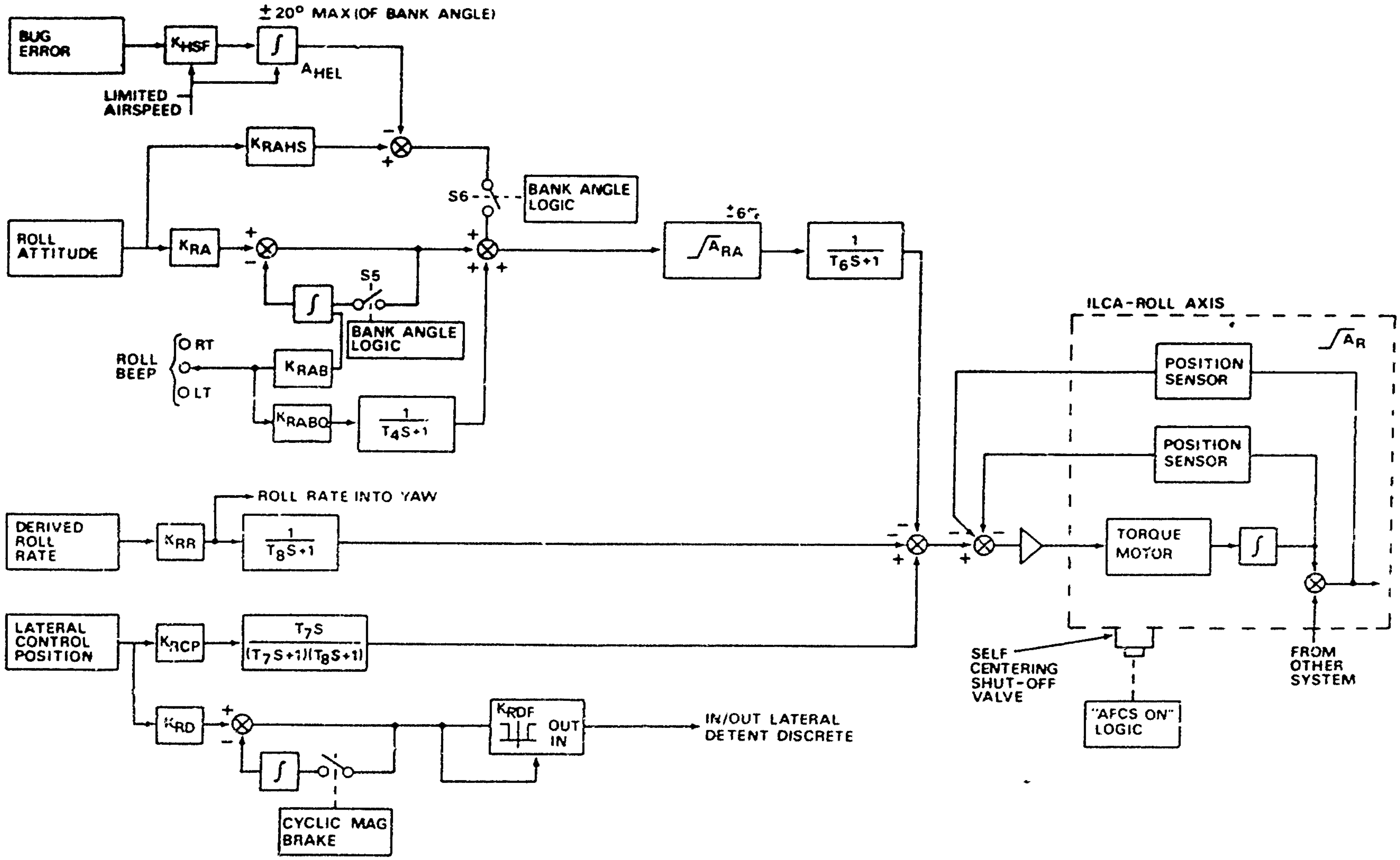
Lateral Control:

8. A block diagram of the lateral control system is shown in figure 9. Rate damping is provided by feeding derived roll rate into the extensible link of the lateral ILCA. The derived roll rate is obtained by electronically differentiating the vertical



NOTE: + sign at servo input causes an extension of No. 1 ILCA, opposite effect for system No. 2.
+ sign at servo input causes an extension of the dash actuator.
See table 2 for values of authorities and limits.

Figure 8. Pitch Control Loops.



NOTE: + sign at servo input causes an extension of system No. 1 ILCA, opposite effect for system No. 2.
See table 2 for values of authorities and limits.

Figure 9. Roll Control Loops.

gyro roll attitude signal. The signal is shaped by a lag to filter noise. A lateral control position transducer opposes the rate gyro signals so that the high stability of the roll AFCS does not degrade lateral maneuverability. Summation of the derived rate signal and the control position signal produces a roll-rate response which is proportional to control displacement. Long-term hold of trim bank attitude is provided by bank-angle inputs from a vertical gyro. Bank-angle error signals from the vertical gyro are used to produce corrective control motions through the extensible link of the roll ILCA. When the pilot displaces the lateral control out of the detent position during maneuvering, the trim bank-angle error is continuously synchronized to zero. When the pilot returns the control to the detent position and the aircraft roll rate is less than 1.5 degree per second, the synchronizer switch opens and the system holds the aircraft at the bank angle stored at the synchronizer output. Vernier beep trim of bank attitude is produced by operation of the lateral beep trim switch. Operation of the lateral beep trim switch adjusts the trim bank angle stored at the synchronizer.

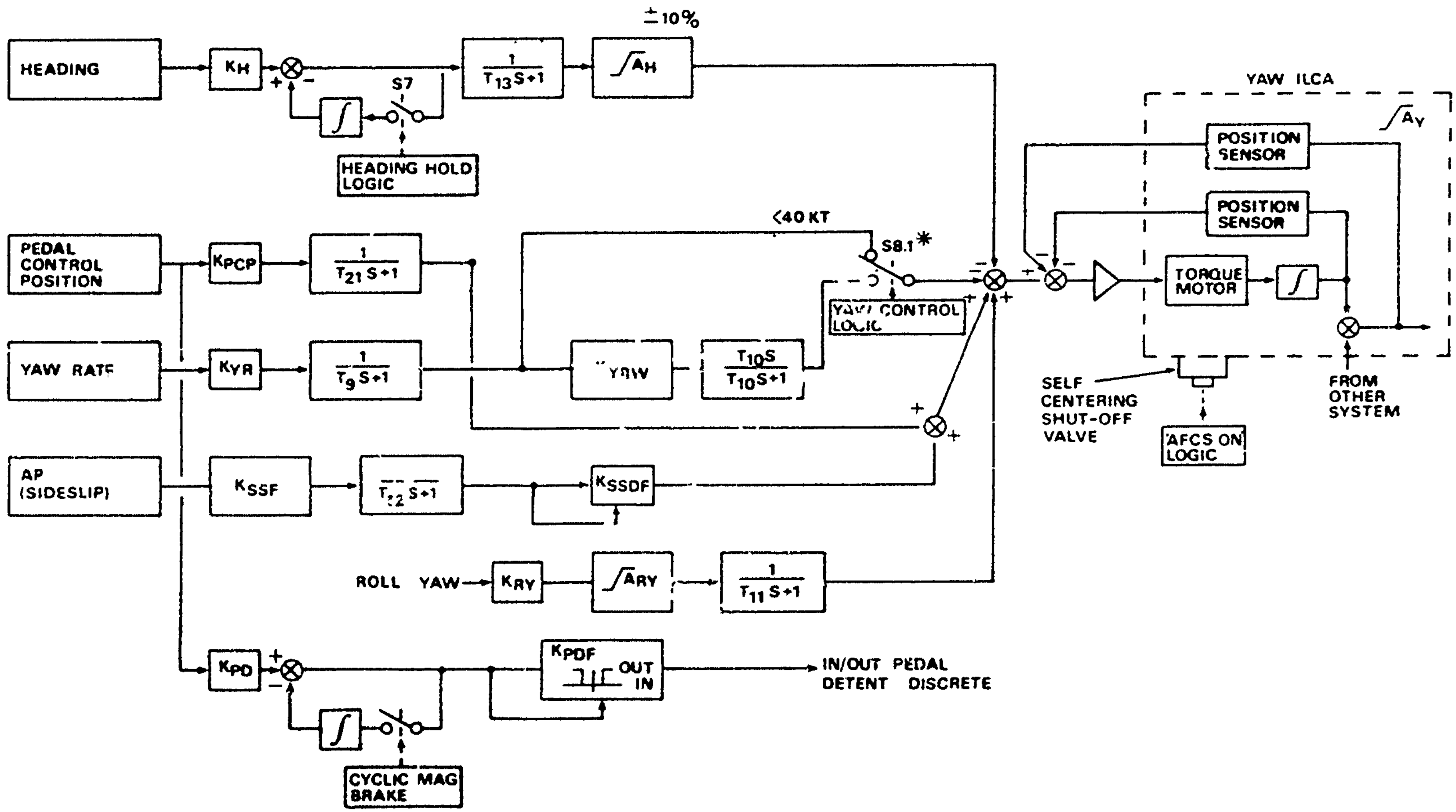
9. A selectible turn coupler mode is available for automatic control of heading. In this mode, the vertical gyro bank angle signal and the course command from the pilots' directional indicator are fed to the extensible link of the lateral ILCA. The system commands a standard rate turn to the commanded course and then holds the aircraft wings level on the course until a new course is commanded. During this mode of flight, the normal bank-angle and heading-hold error signals are synchronized to zero.

Directional Control:

10. As shown in figure 10, yaw rate damping is provided by feeding a signal obtained from a yaw rate gyro to the extensible link of the directional ILCA. At speeds above 40 knots indicated airspeed (KIAS), the yaw rate signal is washed out to prevent saturation and miscoordination in turns. The yaw rate signal is changed between the two states in 5 to 7 seconds when transitoning through 40 knots. The derived roll rate is lagged and fed into the yaw ILCA to provide automatic turn coordination. Static directional stability is artificially enhanced by sideslip pressure transducer signals. Inputs from the pedal position transducer opposes the yaw feedback signals so that the high stability does not degrade directional maneuverability.

11. Heading hold is maintained by comparing a signal from the directional gyro to a reference heading and feeding the heading error into the extensible link on the directional ILCA. At all speeds the heading reference is synchronized to the existing directional gyro signal whenever the cyclic mag brake is depressed or the pedals moved out of detent. When pilot releases the mag brake or returns the pedals to detent and the absolute value of yaw rate becomes less than 1.5 degrees per second, the heading reference locks onto and holds the existing aircraft heading. At speeds above 40 KIAS, the synchronization of heading reference also takes place whenever the lateral control is moved out of detent to permit stick-only turns. When the lateral control is returned to detent and bank angle becomes less than 1.5 degrees, the heading reference again locks onto and holds the existing heading. Finally, the heading reference is synchronized whenever the turn coupler mode is selected.

12. Since both AFCS boxes use the signal from the same directional gyro, the signals are electronically limited to half authority, thereby making the gyro failure mode no worse than a single extensible link hardover.



NOTE: S8 is a fader switch. Time of transfer = 5<T> sec.
+ sign at servo input causes an extension of system No. 1 ILCA, opposite effect for system No. 2.
See table 2 for values of authorities and limits.

Figure 10. Yaw Control Loops.

Thrust Control:

13. Altitude hold (fig 11) is accomplished by comparing the altitude sensor signal to a reference altitude and feeding the error to the CCDA. The CCDA moves the cockpit control to maintain the reference altitude. At any time the altitude hold is turned off or the thrust brake trigger is depressed, the reference altitude is continually synchronized to the altitude sensor signal. When the altitude hold is engaged and the thrust brake trigger is released, the reference altitude locks onto and holds the value on the altitude sensor at that time. The altitude sensor is either the barometric altitude sensor or the radar altimeter depending upon the mode selected. A normal accelerometer signal processed by the AFCS provides the required vertical damping. A bank angle signal is used to offset the normal accelerometer and provide the collective command required to maintain altitude in the turn.

Longitudinal Cyclic Trim:

14. The longitudinal cyclic pitch (fig 12) is automatically programmed with indicated airspeed providing the cyclic trim switch on the AFCS panel is in AUTO. Below 60 knots, the forward and aft rotors are constant at 1.2 degrees and 3.25 degrees aft, respectively. From 60 knots to 150 knots, the cyclic pitch is increased linearly to 4.0 degrees forward on both rotors. In addition both rotors program with pressure altitude at the rate of 2.0 degrees per 10,000 feet.

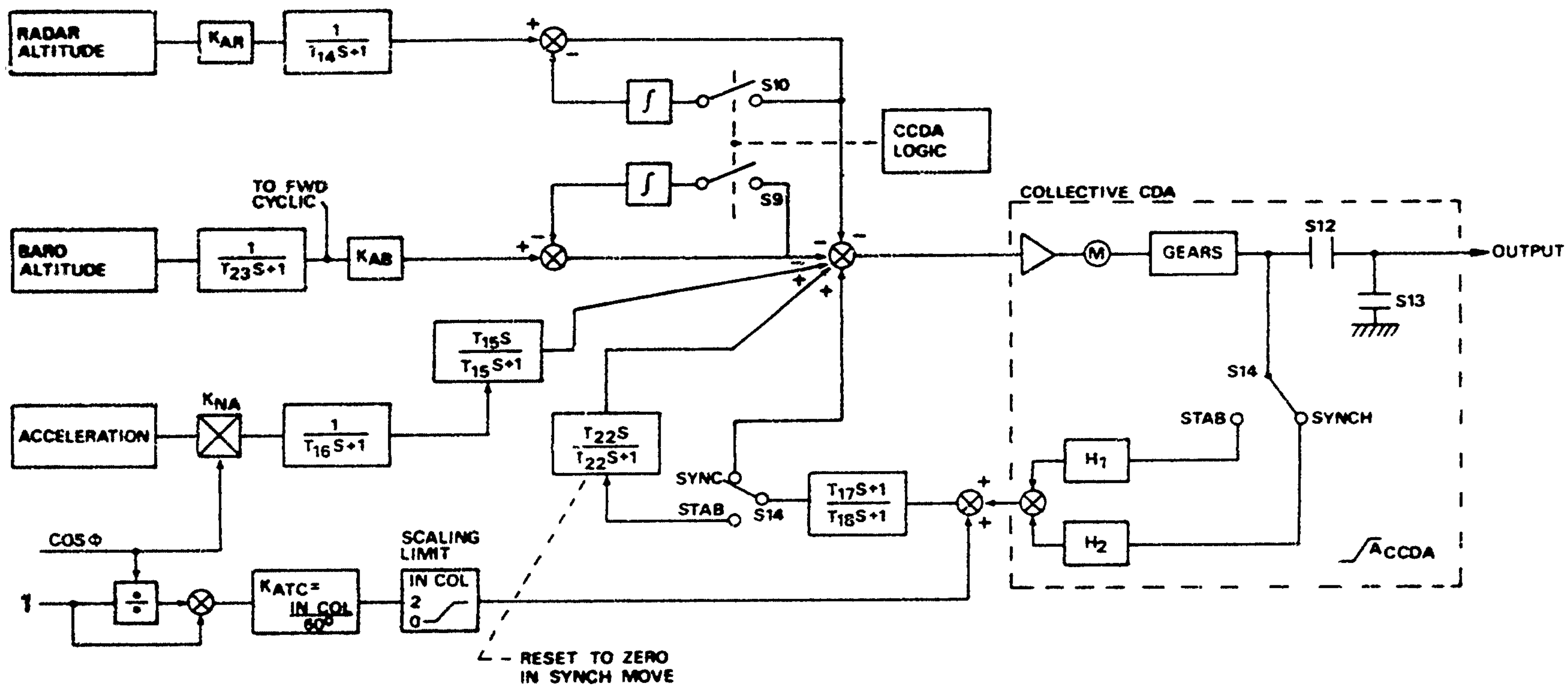
15. When both the left and right landing gear switches indicate ground contact has been made the cyclic pitch on both rotors move to zero degrees to permit taxi or rotor shutdown.

16. In addition to the AUTO modes above, a manual mode is available as on previous CH-47's. When selected the cyclic trim can be beeped to any desired position.

ROTOR BLADES

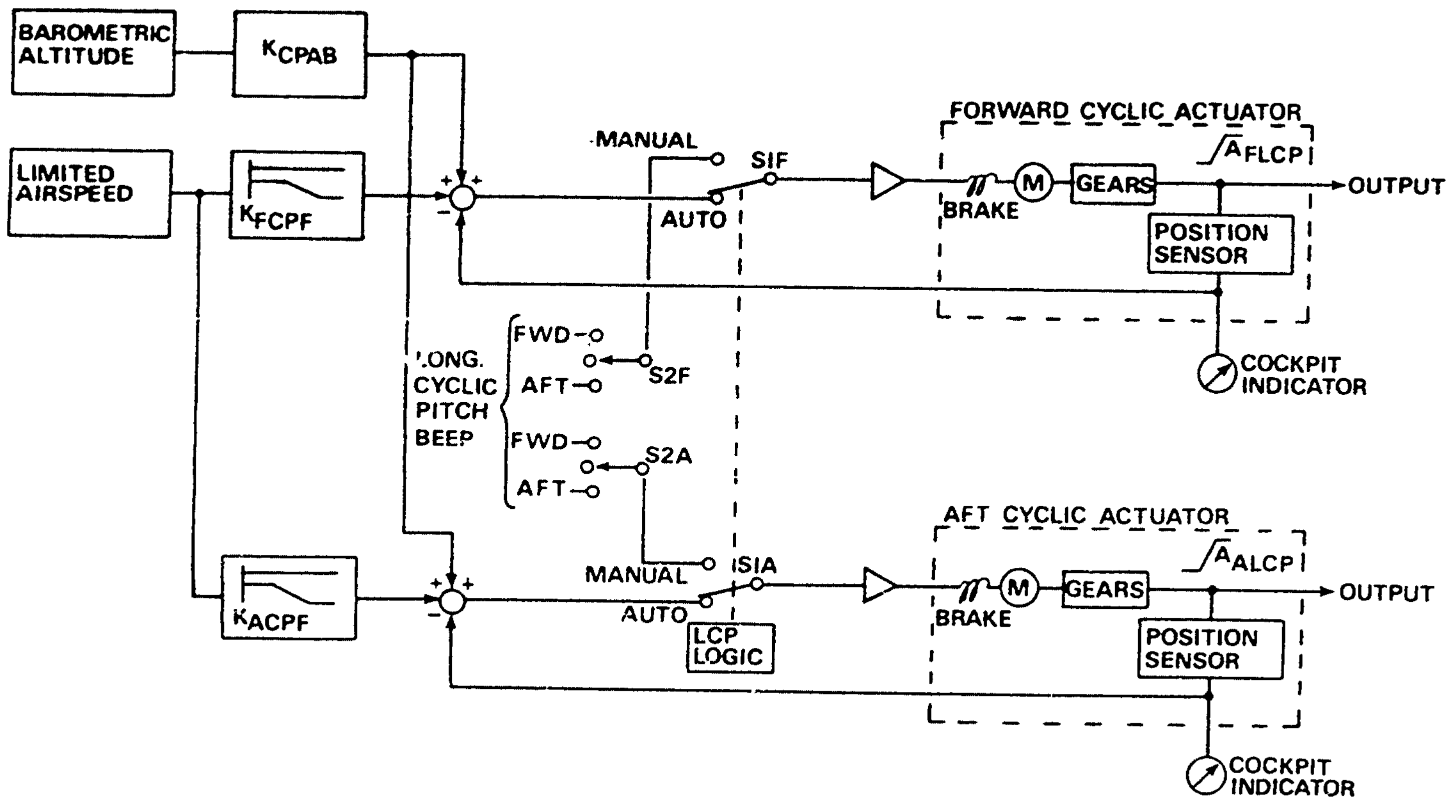
17. The fiberglass rotor blades are of 30-foot radius with a 32-inch chord and operate at 225 rpm. The planform is constant-chord between station 97 and the tip; from station 97 inboard it transitions to a circular root end section. The blades have a 12 percent thick VR-7 airfoil out to 85 percent radius, tapering uniformly to an 8 percent thick VR-8 airfoil at the tip.

18. The blades are of fiberglass construction with a nomex honeycomb core (fig 13). The "D" shaped spar is constructed of fiberglass reinforced composite, terminating at the root end in a "wrap-around" single pin joint. The nose of the spar includes balance weights and provisions for a de-ice heat blanket. Outboard, the spar contains provisions for forward and aft weight fittings. The airfoil fairing aft of the spar is formed from a banded subassembly of nonmetallic honeycomb core covered with cross-plied (±45°) fiberglass skins. The fiberglass trailing edge member has a built in "cusp" angle. A titanium leading edge cap is incorporated to provide leading edge damage tolerance, erosion protection and lightning protection. A replaceable electro-formed nickel protective cap is installed from the 85 percent radius to the tip.



NOTE: + sign at servo causes CCW rotation of CCDA.
See table 2 for values of authorities and limits.

Figure 11. Collective Control Loops.



NOTE: + sign at servo input causes the LCP actuators to extend.
See table 2 for values of authorities and limits.

Figure 12. Longitudinal Cyclic Pitch Control Loops.

(See Figures 8 through 12)

Symbol	Parameters	Value	Tolerance	Units
K_{DAS}	Dash airspeed gain	0.12	±5%	Inches of Equiv. Stick / kn
K_{DPA}	Dash attitude gain	25.6	±5%	Inches of Equiv. Stic / Radian
K_{DLCV}	Dash longitudinal control (velocity) gain	7.5		Inches of Equiv. Stick / Inch of Stick
K_{DLCP}	Dash longitudinal control (proportional) gain	1.1		Inches of Equiv. Stick / Inch of Stick
K_{FCPF}	Forward cyclic pitch function			
K_{CPAB}	Cyclic pitch altitude bias	0.15		Degrees of Cyclic / 1000 feet
K_{ACPF}	Aft cyclic pitch function			
K_{PR}	Pitch rate gain	10.2		Inches of Equiv. Stick / Radian/sec
K_{RA}	Roll attitude gain	11.0		Inches of Equiv. Stick / Radian
K_{RAB}	Roll attitude beep gain	0 05		Radians / sec
K_{RABQ}	Roll attitude beep quickening gain	Zero, but provisions for 0 25 max		Inches of Equiv. Stick
K_{RR}	Roll rate gain	5.7		Inches of Equiv. Stick / Radian/sec
K_{RCP}	Roll control position gain	1.0		Inches of Equiv. Stick / Inch of Stick
K_{HSF}	Heading select function	See fig.		
K_{RAHS}	Roll attitude-heading select gain	14.3		Inches of Equiv. Stick / Radian
K_{H}	Heading gain	8.2		Inches of Equiv. Stick / Radian
K_{RY}	Roll into yaw gain	5 7		Inches of Equiv. Pedal / Radian
K_{SSDF}	Sideslip displacement function			
K_{NA}	Normal acceleration in gain	2.4		Inches of Equiv. Stick / ft/sec²
K_{AR}	Altitude - radar gain	0.055		Inches of Equiv. Stick / ft
K_{AB}	Altitude - barometric gain	0 024		Inches of Equiv. Stick / ft
K_{PCP}	Pedal control position gain	1 0		Inches of Equiv Pedal / Inch of Pedal
K_{YR}	Yaw rate gain	8.0		Inches of Equiv Pedal / Radian/sec
K_{YRW}	Yaw rate washout gain	1.0 (Dimensionless)		
K_{RD}	Roll detent gain	1.0		
K_{RDF}	Roll detent function			
K_{PD}	Pedal detent gain	1 0		
K_{PDF}	Pedal detent function			
K_{SSF}	Sideslip function		±10% of value	
V_{DASH}	Dash longitudinal control velocity limit (dual system)	0.5		Inches of Equiv. Stick

NOTE The listed gains are dual system values.

CH-47 FIBERGLASS ROTOR BLADE — ARTICULATED

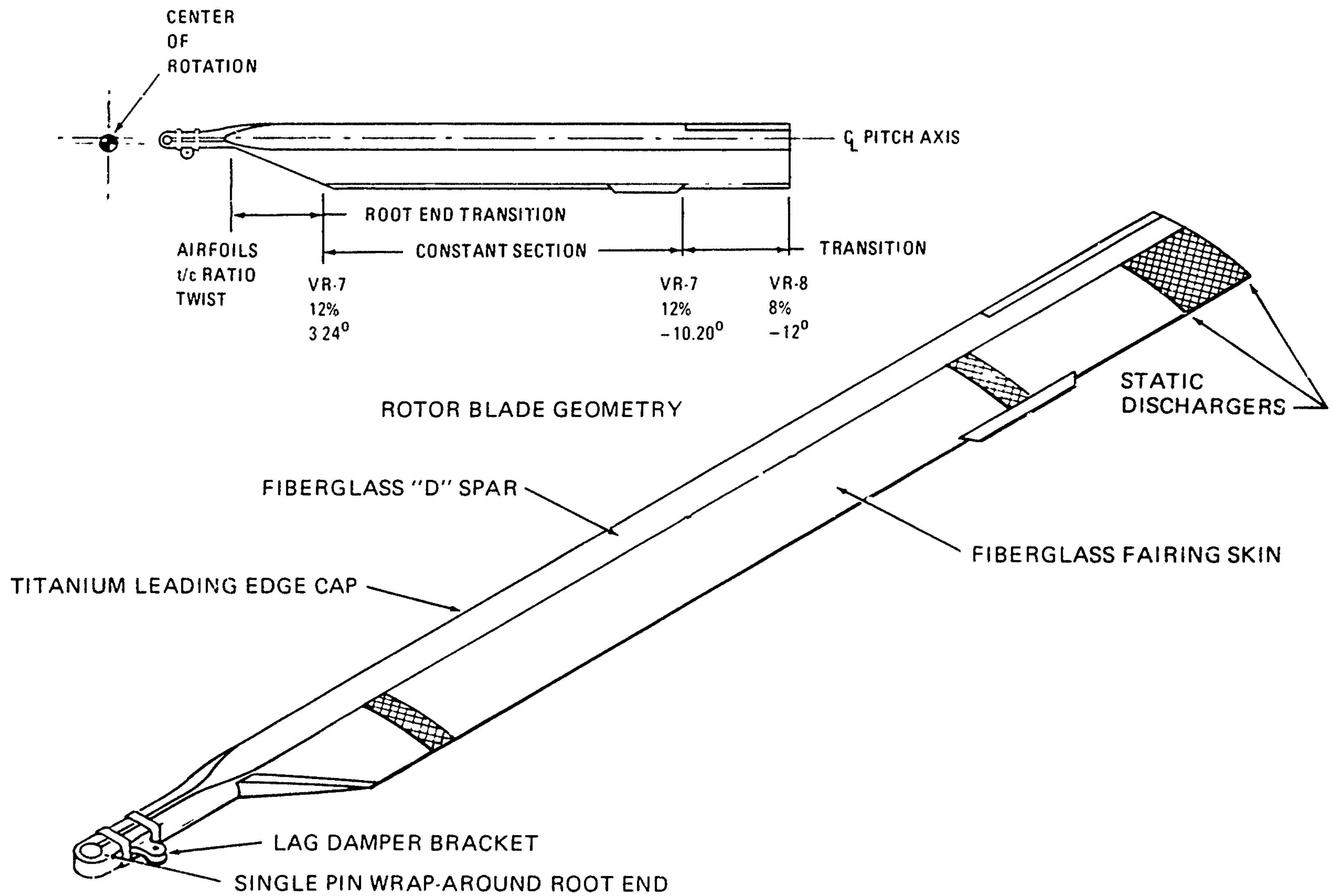


Figure 13. Fiberglass Rotor Blade

ENGINES

19. The T55-L-712 engine incorporates improved maintainability and performance capability when compared with earlier T55 models. The engine also has the capability to produce emergency power on pilot demand. The power levels for non-installed, sea lever, standard static conditions and 15,066 engine RPM (225 rotor RPM) are presented below:

Emergency Power (30 min, cumulative)	4,320 SHP
Maximum Power (10 min)	3,704 SHP
Intermediate Power (30 min)	3,370 SHP
Maximum Continuous Power	2,987 SHP

TRANSMISSIONS

20. The YCH-47D transmission system includes features that reduce vulnerability and improve reliability. The forward, aft and combiner transmissions include independent lubrication with the forward and aft transmissions having integral cooling blowers and heat exchangers. In addition to the separate oil systems, an auxiliary (redundant) source of lubrication, capable of maintaining safe operation for two hours, is provided. The forward, aft, and combiner transmissions are also capable of operating for 30 minutes after loss of both main and auxiliary oil pressure. Increased reliability is incorporated by use of improved materials, increased gearing and bearing capacity, increased bearing life, reduced shaft and spline stress levels and tuning of dynamic components to reduce motion amplitudes.

HYDRAULIC SYSTEMS

21. The hydraulic systems consist of dual modularized flight control systems and a modularized utility hydraulic system. Both flight control systems operate at 3000 psi and separately and independently operate the dual upper control actuators and ILCA's. The systems are modularized (prepackaged hydraulic components having a standard outline) and provide two power control modules, two reservoir/cooler modules, two fans, two lower control pressure control modules, two transmission mounted pumps, two power transfer units and a hydraulic maintenance panel. The utility system provides hydraulic power for both flight and ground utility functions and ground checkout of the flight control system.

ELECTRICAL SYSTEMS

22. The YCH-47D electrical system is a first fail-operative, second fail-safe system capable of serving all required electrical loads during flight and ground operation. The primary electrical system is 115/200 volt 400 Hz alternating current. Electrical power is furnished by two AC, oil cooled, brushless, generators mounted on the aft transmission. The APU drives a 20 KVA generator which provides power for ground service and checkout functions. The AC bus system provides electrical isolation of generator outputs. The DC power is supplied by two transformer-rectifier units (TRU), each connected to an isolated bus. The TRU's are physically isolated to reduce vulnerability and a bus tie relay automatically connects the two buses together in the event of failure in either unit.

EXTERNAL CARGO SYSTEM

23. The external cargo system consists of three cargo hooks mounted under the aircraft. The center hook has a 28,000 lb capacity while the fore and aft hook have a 20,000 lb capacity. The system is capable of carrying loads individually or simultaneously on all of the hooks.

APPENDIXC. INSTRUMENTATION

General

1. Test instrumentation was installed, calibrated, and maintained by Boeing Vertol Co. (BV). Data was displayed in the cockpit, recorded on on-board magnetic tape, and relayed via telemetry to STARLAB at the BV Philadelphia facility. It was processed and then microwaved to the BV Wilmington flight test facility, where the real time data were monitored by the project engineer. The instrument package is shown in photograph 1.

2. Instrumentation for the test is listed below.

- Airspeed, production (pilot)
- Airspeed, boom (copilot)
- Altitude, pressure (production)
- Altitude (boom)
- Total air temperature
- Rotor speed (sensitive)
- Event marker
- 1/rev signal
- Control position
  - Longitudinal
  - Lateral
  - Thrust
  - Directional
- Sideslip angle
- Attitude
  - Pitch
  - Roll
  - Yaw
- Fuel totalizer, engine numbers 1 & 2
- Fuel flow, engine numbers 1 & 2
- Fuel temperature, engine numbers 1 & 2
- Engine torque, engine numbers 1 & 2
- Time
- Event counter
- Cyclic trim (fwd)
- Cyclic trim (aft)
- Rotor speed (coarse)
- Angular rates:
  - Pitch
  - Roll
  - Yaw
- Angle of attack (boom)
- Cruise guide indicator
- Gas generator speed (N_1), engine numbers 1 & 2
- Engine condition lever position, engine numbers 1 & 2
- Turbine gas temperature, engine numbers 1 & 2
- Tether cable angle
  - Longitudinal
  - Lateral
- Forward rotor torque (3 channels)
- Aft rotor torque (3 channels)

Tether cable load - AXIAL
Center hook beam stress (tension)
Vibrations (accelerometer location)

- Pilot seat vertical acceleration
- Pilot seat lateral acceleration
- Pilot seat longitudinal acceleration
- Center of gravity acceleration vertical
- Center of gravity acceleration lateral
- Center of gravity acceleration longitudinal
- Station 95 center line lateral
- Station 95 center line longitudinal
- Station 95 center line vertical
- Station 50 left hand vertical
- Station 50 right hand vertical

ILCA SCAS position

- Number 1 pitch
- Number 2 pitch
- Number 1 roll
- Number 2 roll
- Number 1 yaw
- Number 2 yaw

Dash actuator position (lower and upper)
Left hand squat switch
Right hand squat switch
Forward swivel actuator position
Forward pivot actuator position
Aft swivel actuator position
Aft pivot actuator position

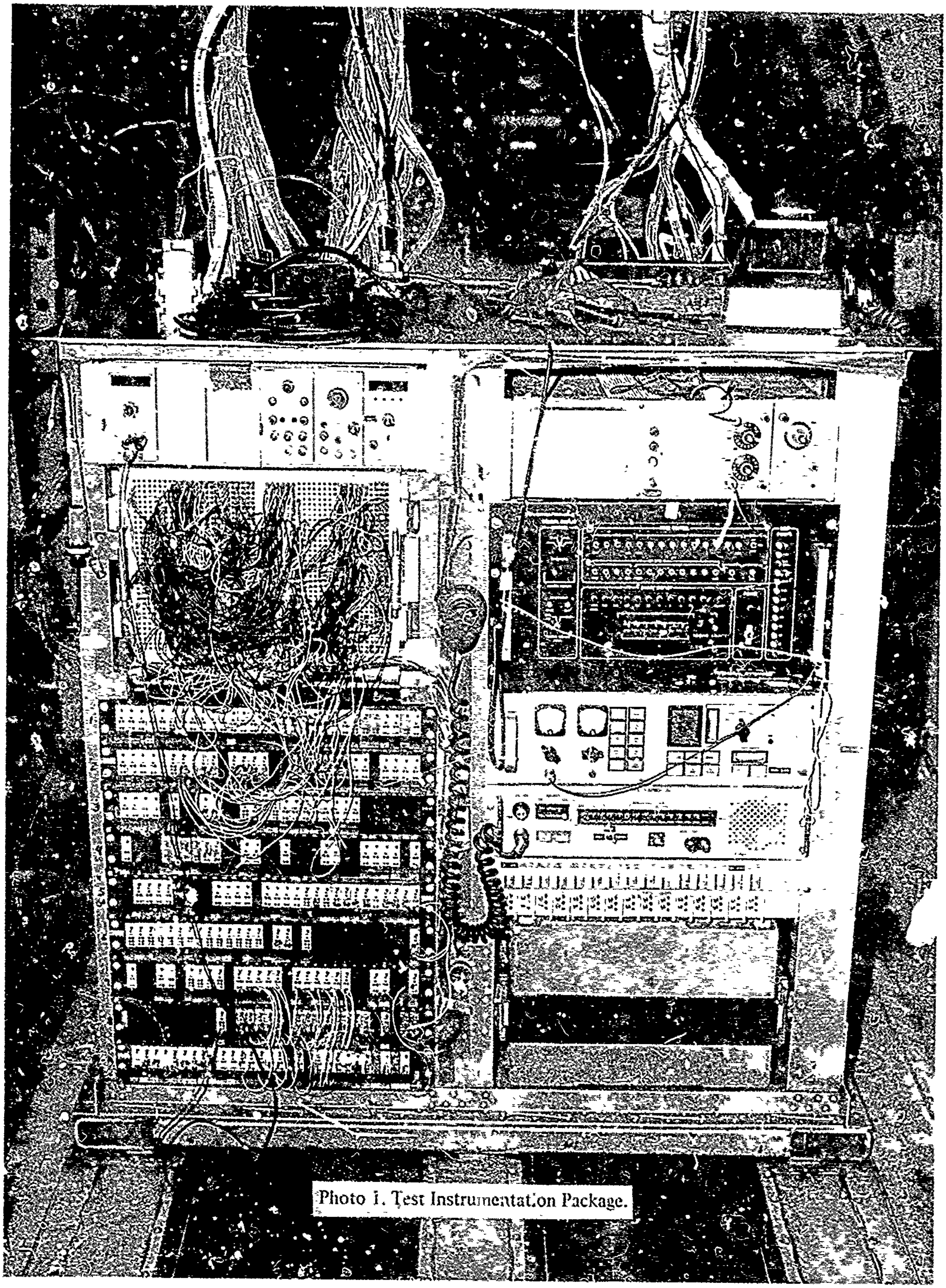


Photo 1. Test Instrumentation Package.

APPENDIX D. TEST TECHNIQUES AND DATA ANALYSIS METHODS

NONDIMENSIONAL COEFFICIENTS

1. The nondimensional coefficients listed below were used to generalize the hover and level flight data obtained during this evaluation.

a. Coefficient of power:

$$C_P = \frac{SHP \times 550}{\rho A (\Omega R)^3} = \frac{SHP/\delta\sqrt{\theta} \times 550}{\rho_0 A (\Omega R/\sqrt{\theta})^3}$$

b. Coefficient of thrust:

$$C_T = \frac{W}{\rho A (\Omega R)^2} = \frac{GW/\delta}{\rho_0 A (\Omega R/\sqrt{\theta})^2}$$

c. Advancing blade tip mach number (M_{tip}):

$$M_{tip} = \frac{1.6878\ V_T + (\Omega R)}{a} = \frac{1.6878\ V_T/\sqrt{\theta} + (\Omega R/\sqrt{\theta})}{1116.45}$$

Where:

SHP	= Output shaft horsepower
550	= Conversion factor (ft-lb/sec/shp)
ρ_0	= Air density (slug/ft^3)
A	= Main rotor disc area (ft^2) (5655 ft^2)
Ω	= Main rotor angular velocity (radian/sec) = $\frac{\pi}{30}$ x RPM
$\Omega/\sqrt{\theta}$	= Referred main rotor angular velocity = $\frac{\pi}{30} \times \frac{N}{\sqrt{\theta}}$
R	= Main rotor radius (ft) (30 ft)
N	= Main rotor rotational speed, RPM
W	= Aircraft gross weight (lb)
V_T	= True airspeed (kt)
$V_T/\sqrt{\theta}$	= Referred true airspeed

a = Speed of sound (ft/sec - $1116.45\sqrt{\theta}$)

1.6878 = Conversion factor (ft/sec/kt)

θ = Temperature ratio = $\frac{(OAT + 273.15)}{288.15}$

POWER DETERMINATION

2. Power for the T55 engine was determined by two methods: measured fuel flow and rotor torque. Both fuel flow and rotor torque were recorded on PCM tape. Engine shaft horsepower (ESHP), fuel flow utilized the Lycoming engine test stand calibration. Rotor torque was measured at each rotor shaft by use of calibrated strain gages to determine rotor horsepower (RHP). Both methods utilized the Boeing Computer Services (BCS) CH-47 Real Time Performance program (ref 12, app A) to calculate shaft horsepower. The relationship between these two methods of determining shaft horsepower is reflected in this equation.

$$RHP = (ESHP - 225) \times 0.9855$$

There was good agreement between RHP and ESHP using this equation. The difference between the shaft horsepower from fuel flow measurements and rotor torque represents transmission loss. This transmission loss compares favorably with this sum of the component losses determined in bench tests by BV.

HOVER

3. Hover performance was obtained both IGE and OGE by the tethered hover technique. All hover tests were conducted in winds of less than 3 knots. Atmospheric pressure, temperature, and wind velocity were recorded from a ground weather station. The tethered hover tests consisted of stabilizing the helicopter, with cable and load cell attached to the ground, at predesignated rotor speeds and power settings. The power setting was varied from the minimum required to maintain cable tension to the maximum allowed by the airworthiness release (105% torque at 217.6 rpm). Rotor speed was varied from 216 to 238 rpm in 5-rpm increments. All hover data were reduced to the nondimensional parameters of C_P and C_T. These data are presented in figures 1 and 2, appendix E.

LEVEL FLIGHT

4. Level flight speed-power performance was determined using referred gross weight, shaft horsepower, and true airspeed. Each speed-power polar was flown maintaining a constant referred gross weight (W/δ) and referred rotor speed ($N/\sqrt{\theta}$). A constant W/δ was maintained by increasing altitude as the aircraft gross weight decreased due to fuel burnoff. Rotor speed was varied to maintain a constant $N/\sqrt{\theta}$ as the outside air temperature varied.

W/δ = Weight divided by pressure ratio
$N/\sqrt{\theta}$ = Rotor speed divided by square root of the temperature ratio

5. The raw data were reduced to referred terms: $SHP/\delta\sqrt{\theta}$, $V_T/\sqrt{\theta}$, W/δ, and $N/\sqrt{\theta}$. Each point was then corrected to unaccelerated flight, zero rate of climb,

aim W/δ, aim $N/\sqrt{\theta}$, and equivalent flat plate area due to nonproduction aircraft configuration. Adjustments to the forward flight data were made to properly account for the configuration differences which existed between the test aircraft and a standard CH-47C. These differences represented a total drag increase of 3.62 ft^2, as defined below.

Item	Flat Plate Area (ft^2)	Data Basis
Rotor instrumentation packages	3.30	Wind tunnel test
Airspeed nose boom	0.32	Estimated

The airspeed boom drag is an estimated value, while the rotor package drag is based on the 1/8 scale model test. A 100% propulsive efficiency was assumed when converting drag to power. The data reduction and corrections were performed utilizing the B-V CH-47 Real Time Performance Program.

CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT

6. Control positions and aircraft attitudes as functions of airspeed were determined during level flight performance.

STATIC LONGITUDINAL STABILITY

7. The static longitudinal stability tests were accomplished by establishing the trim condition and then varying longitudinal control positions to obtain airspeed changes about the trim airspeed with collective control held fixed at the trim value. The airspeed range of interest was approximately ±20 knots from trim. Altitude was allowed to vary as required during the test.

STATIC LATERAL-DIRECTIONAL STABILITY

8. These tests were conducted by establishing the trim condition and then varying sideslip angle incrementally up to the limits of the sideslip envelope or until full directional control was reached. During each test, collective control position, airspeed, and aircraft ground track were held constant and altitude allowed to vary as required.

MANEUVERING STABILITY

9. This test was accomplished by establishing the trim condition and then incrementally increasing load factor by increasing roll attitude (in both directions) while holding airspeed and collective control position constant and allowing altitudes to vary as necessary.

DYNAMIC STABILITY

10. Dynamic longitudinal and lateral-directional stability were qualitatively evaluated to determine both the short- and long-period characteristics. The short-period response was evaluated by use of longitudinal and lateral cyclic and directional pulse inputs to all flight controls in both directions. The long-period dynamic response was evaluated longitudinally by slowly returning the flight controls to trim position following a decrease of 10 knots indicated airspeed (KIAS) from the trim airspeed and in the lateral-directional mode by a release from a steady-heading sideslip.

CONTROLLABILITY

11. Controllability tests were accomplished by applying longitudinal, lateral and directional step inputs of three magnitudes (approximately 1/4, 1/2, and 1 inch) in both directions. The input was made by rapidly displacing the control (less than 0.1 second) from trim, against a control fixture. The input was held until a steady-state rate was obtained or recovery was necessary. All controls, other than the input control, remained fixed. In forward flight, the inputs were initiated during unaccelerated ball-centered level flight. The hover controllability test was conducted in winds of 3 knots or less, at a rear wheel height of approximately 30 feet.

12. A Handling Qualities Rating Scale was used to augment pilot comments and is presented as figure 1. The Vibration Rating Scale (VRS) was used to augment pilot comments on vibrations and is presented as figure 2.

VIBRATIONS

13. Specification vibration accelerations were measured at station 95 and 320 BL 25. The aircraft was flown in the 33 troop configuration with 240 pounds of ballast in each troop seat and at a rotor rpm of 225. The aircraft was flown below 2000 feet density altitude at hover and an airspeed sweep from 40 to V_{max}. A 20 rotor cycle sample of data was taken at each test condition and harmonically analyzed. The 85th percentile of this sample was plotted in figure 69 and 70

APPENDIX E. TEST DATA

INDEX

FIGURE 1
NON-DIMENSIONAL HOVER PERFORMANCE
CH-47D USA S/N 76-18479
FIBERGLASS ROTOR BLADES
IN GROUND EFFECT
10 FOOT TETHERED HOVER

NOTES: 1. WHEEL HEIGHT MEASURED FROM BOTTOM OF RIGHT REAR WHEEL
2. WIND LESS THAN 3 KNOTS
3. AVERAGE OAT = -4.4°C
4. AVERAGE DENSITY ALTITUDE = -30 FEET

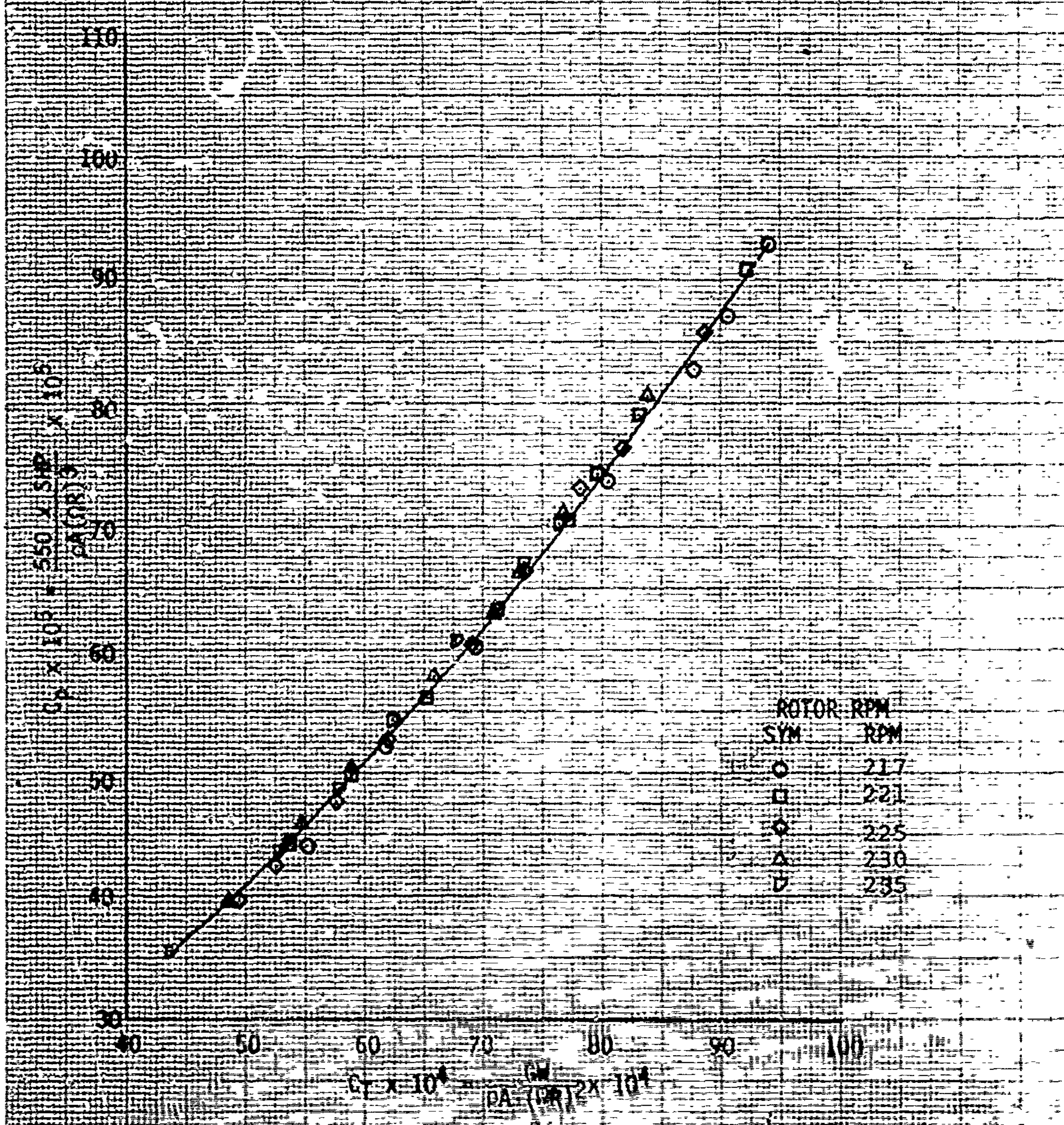


FIGURE 2

NON-DIMENSIONAL HOVER PERFORMANCE
CH-47D USA S/N 76-18479
FIBERGLASS ROTOR BLADES
OUT OF GROUND EFFECT
150 FOOT TETHERED HOVER

NOTES: 1. WHEEL HEIGHT MEASURED FROM BOTTOM OF RIGHT REAR WHEEL
2. WIND LESS THAN 3 KNOTS
3. AVERAGE OAT 16°C
4. AVERAGE DENSITY ALTITUDE 30 FEET

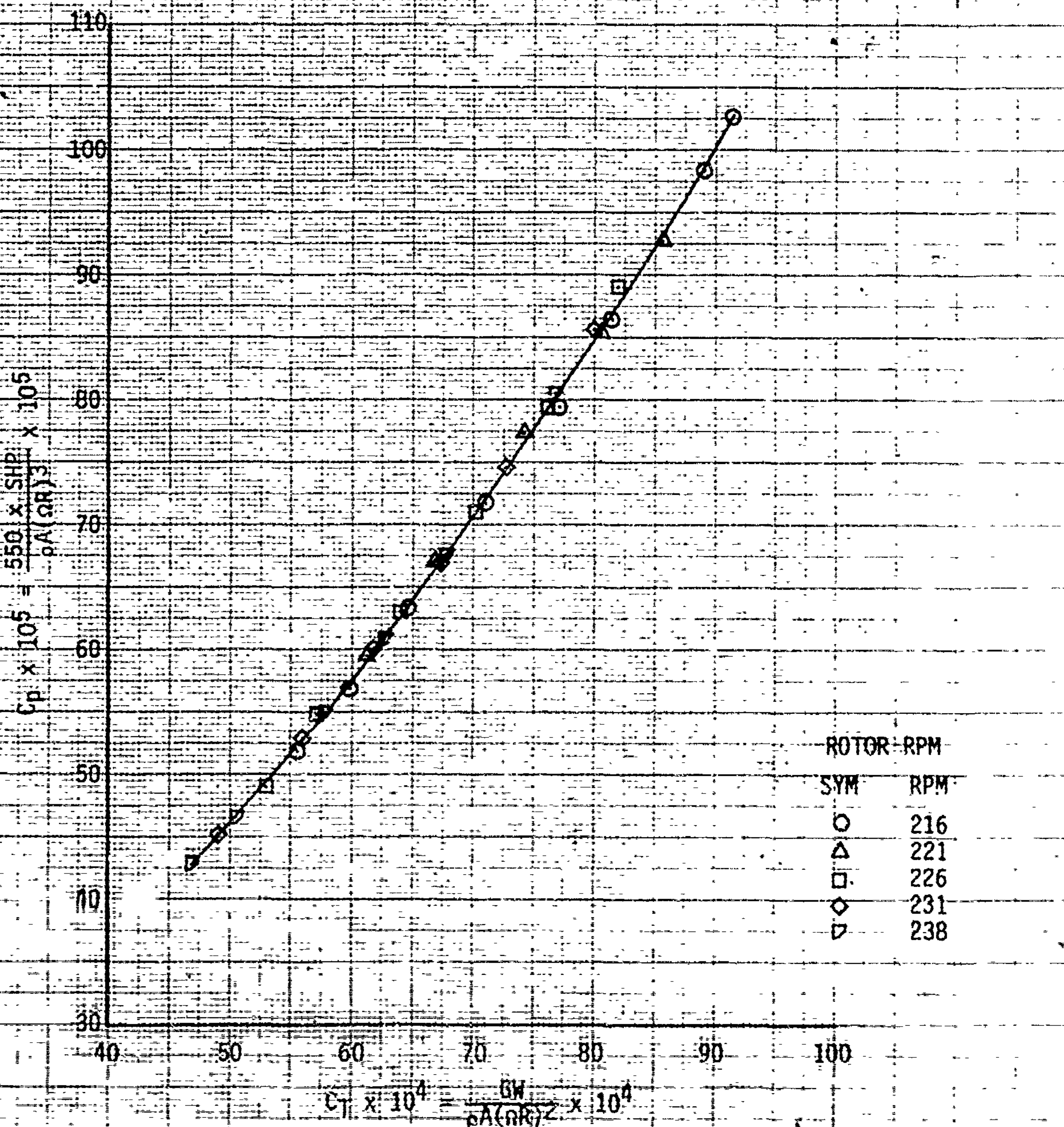


FIGURE 3
LEVEL FLIGHT PERFORMANCE
YCH-47D USA S/N 76-18479
$N/\sqrt{\theta} = 225$

SYM	AVG REF GROSS WT (LB)	AVG PRESS ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG C_T
○	33579	2500	11	327	0.00500
□	40295	9200	6	327	0.00600
◇	47011	2200	12	336	0.00700
⊳	52625	7000	6	336	0.00784
▽	60443	9300	2	336	0.00900

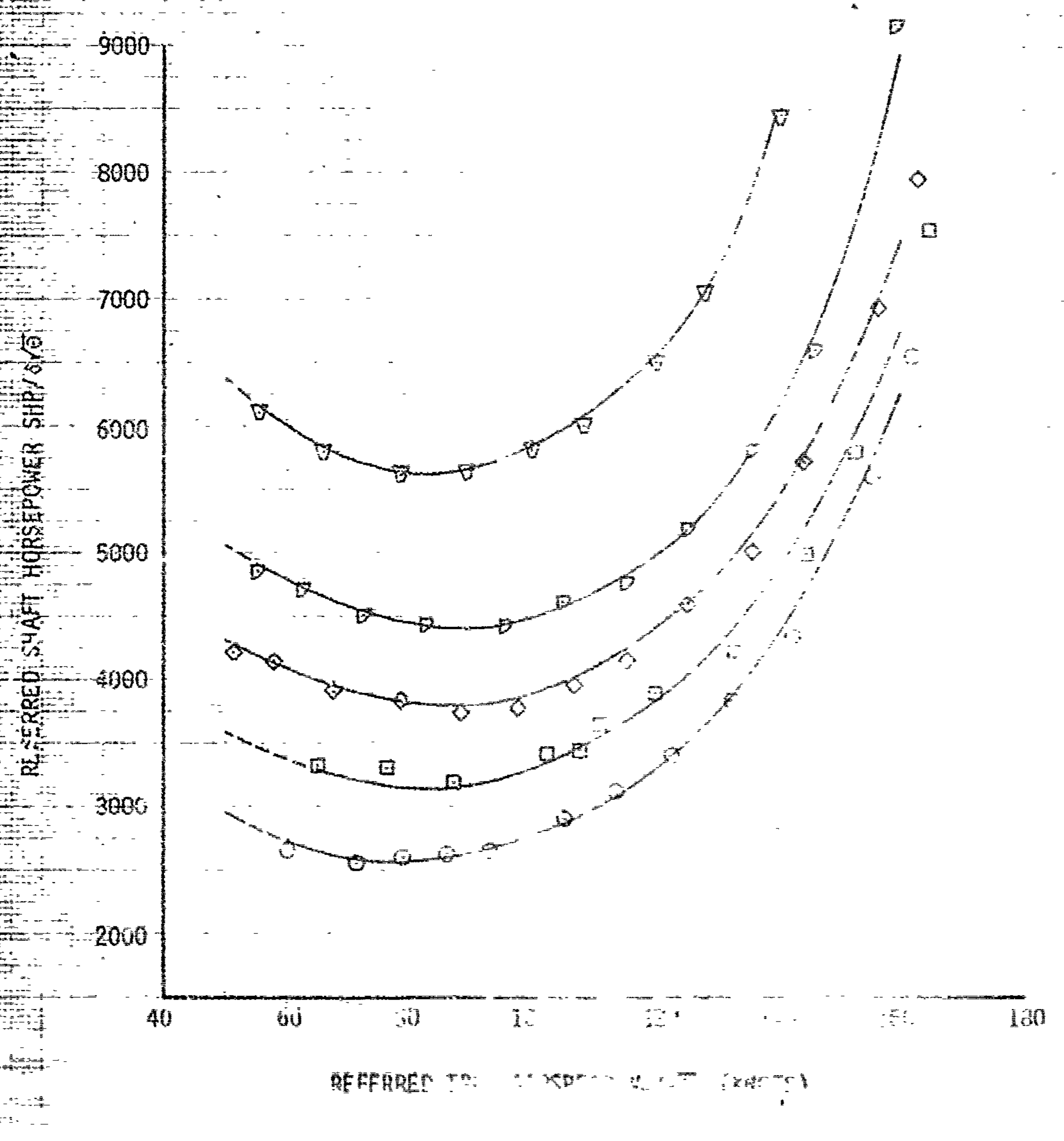


FIGURE 4
LEVEL FLIGHT PERFORMANCE
YCH-47D USA S/N 76-18479
$N/\sqrt{\theta} = 225$

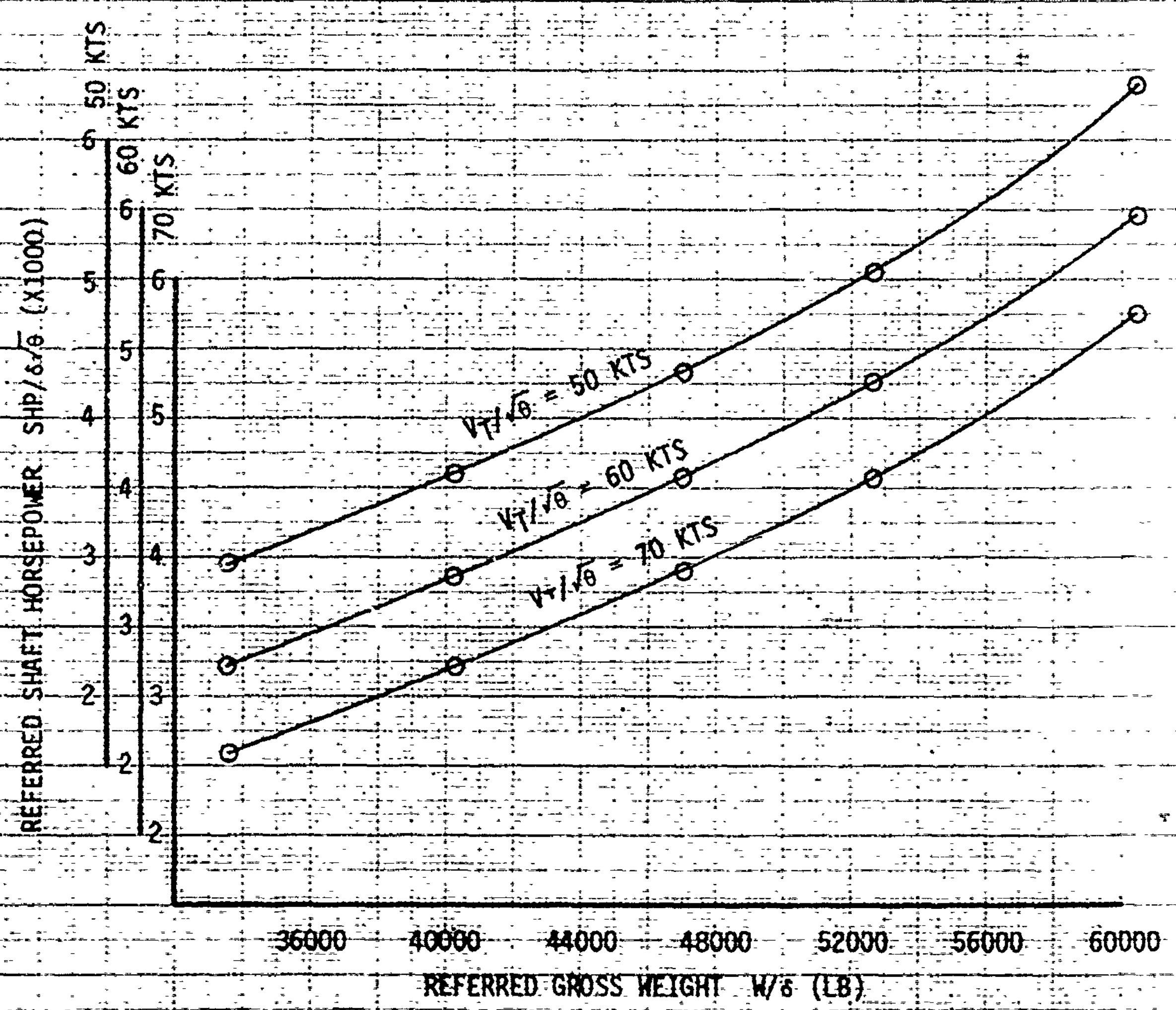


FIGURE 5
LEVEL FLIGHT PERFORMANCE
YCH-47D USA S/N 76-18479
$N/\sqrt{\theta} = 225$

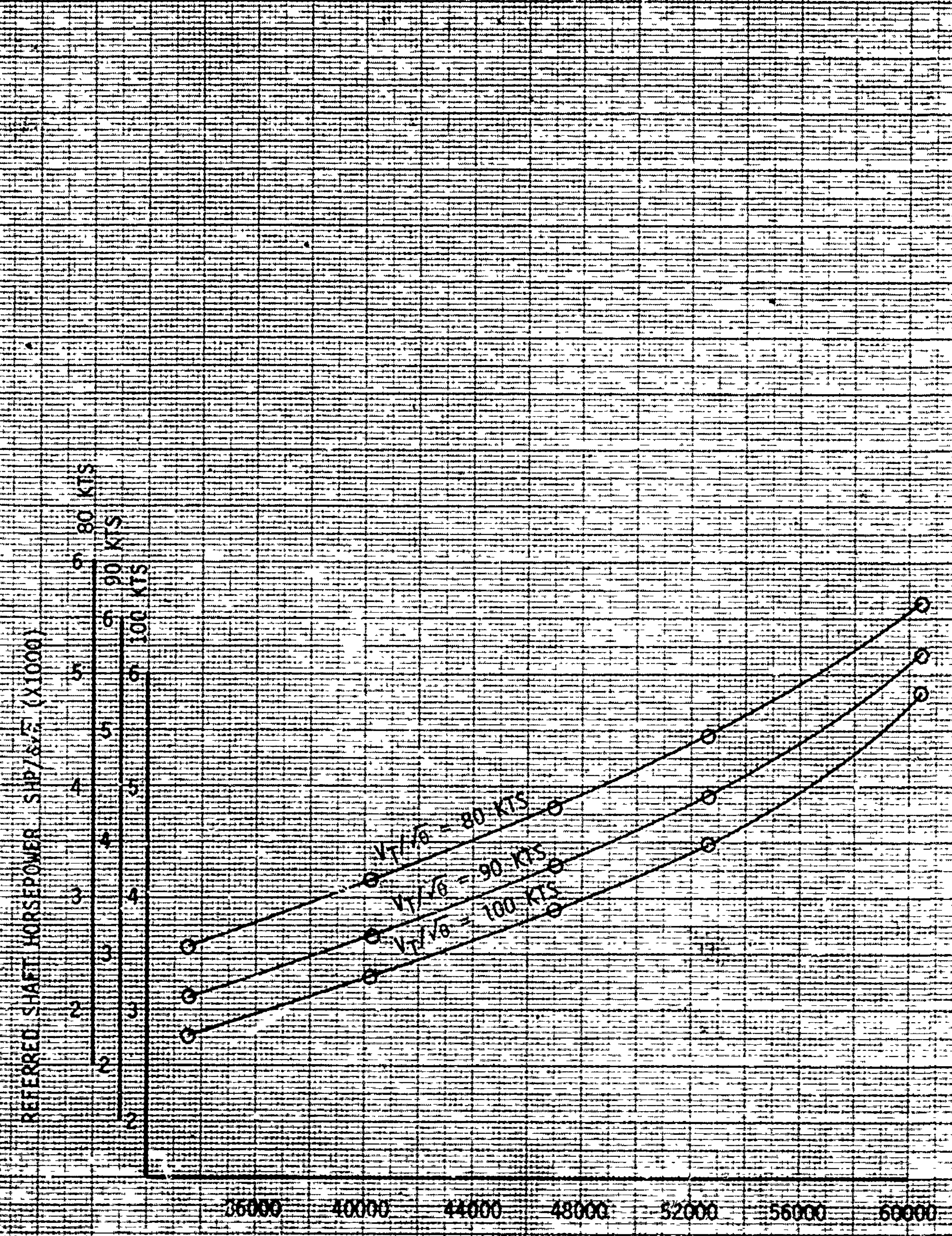


FIGURE 6
LEVEL FLIGHT PERFORMANCE
YCH-47D USA S/N 76-18479
$N/\sqrt{\theta} = 225$

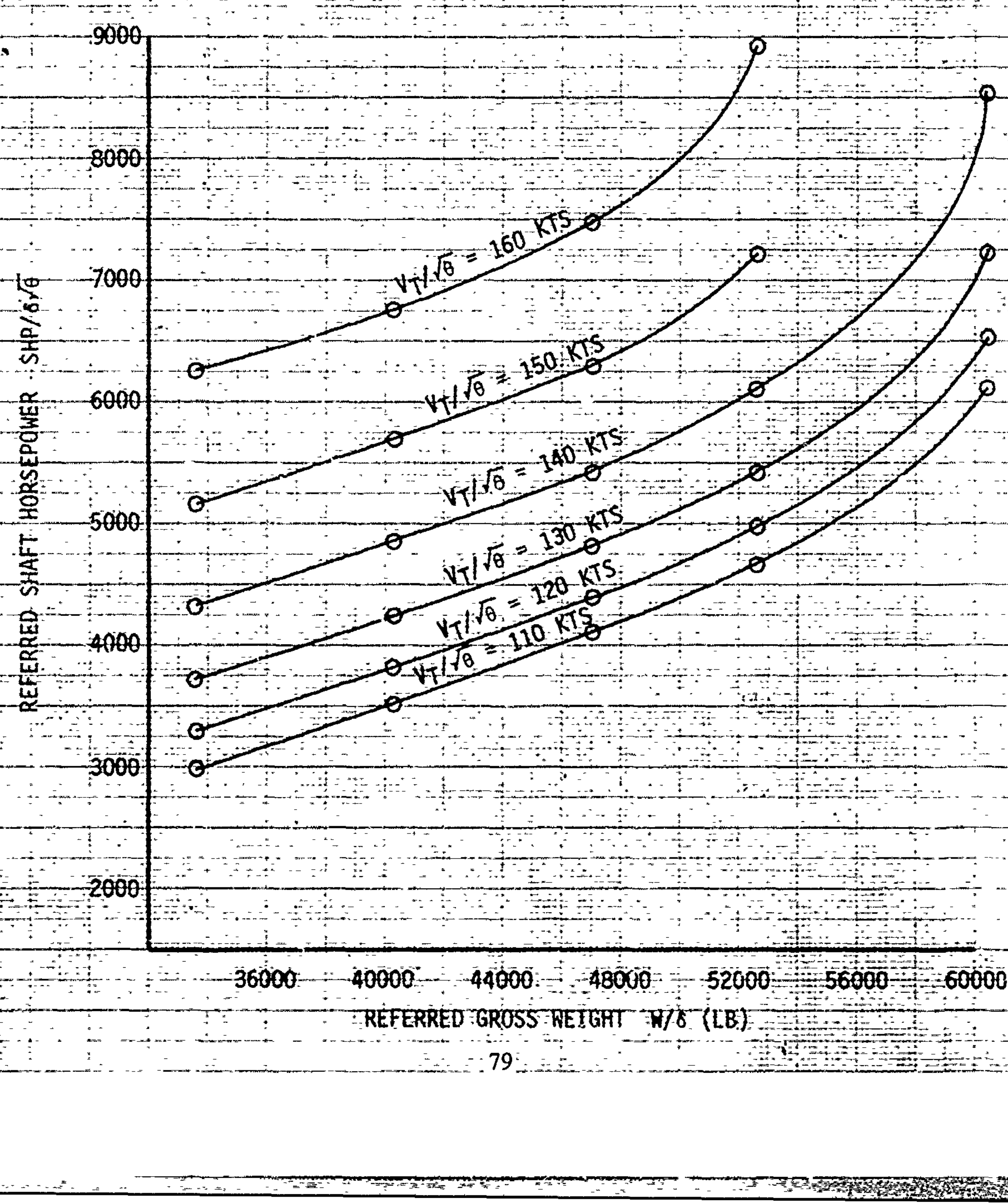


FIGURE 7
LEVEL FLIGHT PERFORMANCE
YCH-47D USA S/N 76-18479
$N/\sqrt{\theta} = 235$

SYM	AVG REF GROSS WT (LB)	AVG PRESS. ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG C_T
○	36630	4560	7	327	0.0050
□	57407	9260	2	336	0.00784
△	65934	7900	-1	331	0.0096

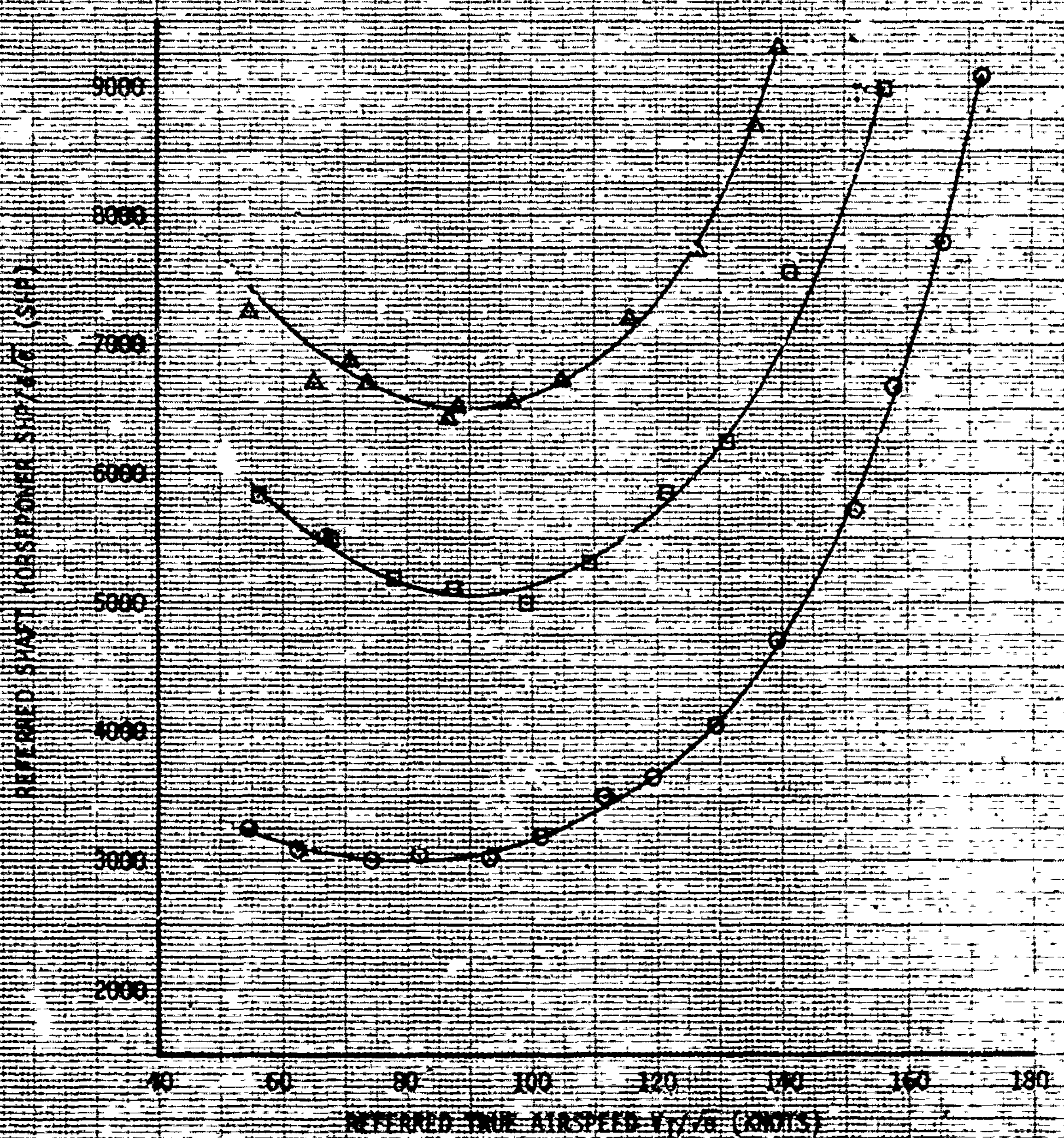


FIGURE 8
LEVEL FLIGHT PERFORMANCE
YCH-47D USA S/N 76-18479
$N/\sqrt{\theta} = 245$

SYM	AVG REF GROSS WT (LB)	AVG PRESS. ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG C_T
△	39814	6380	2	328	0.0050
□	62396	7100	1	332	0.00784
○	71664	9540	-4	331	0.0090

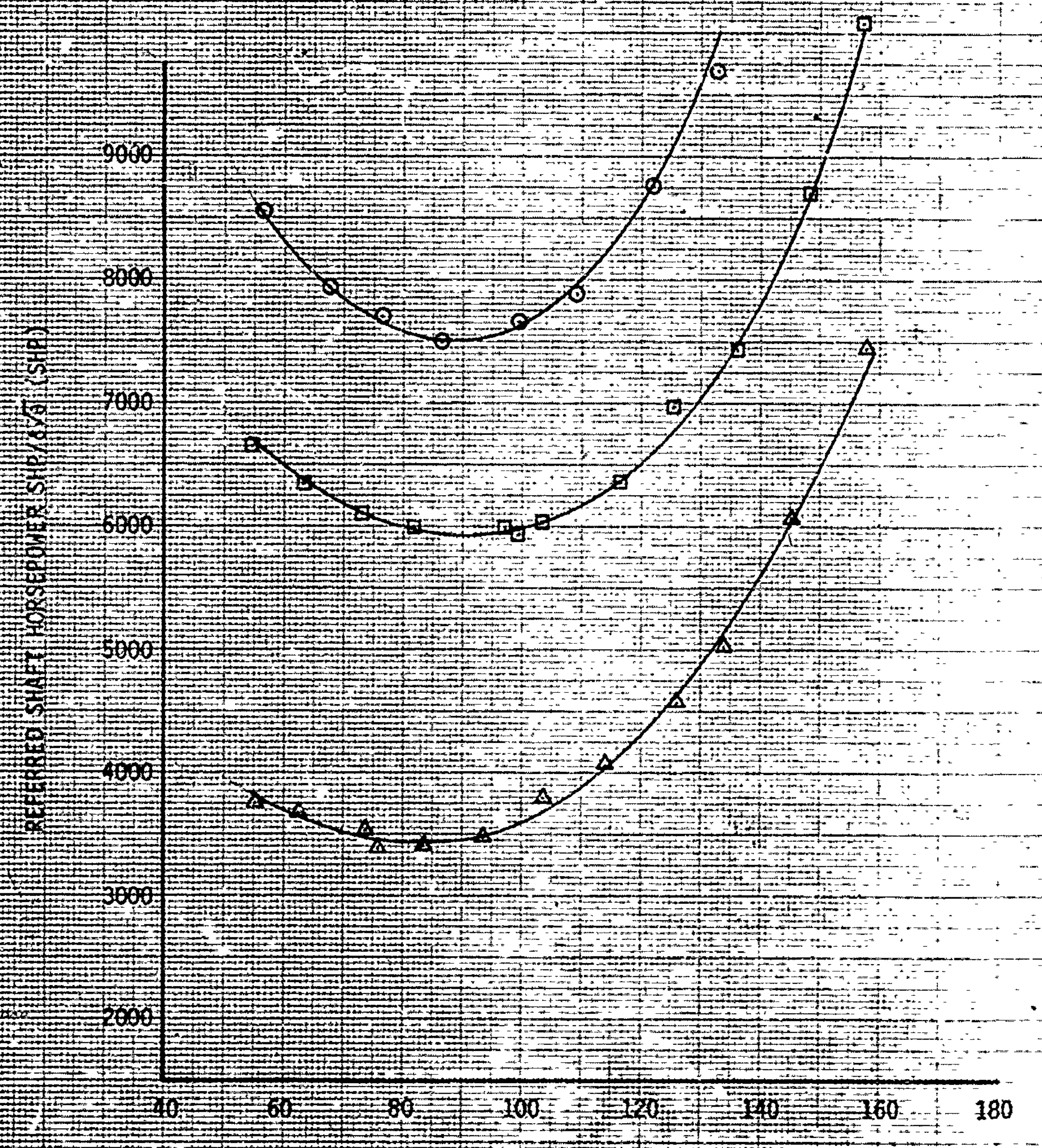


FIGURE 9
LEVEL FLIGHT PERFORMANCE
YCH-47D USA S/N 76-18479
2 POINT SLING LOAD XM-198
$N/\sqrt{\theta}$ = 225

SYM	AVG REF GROSS WT (LB)	AVG PRESS. ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG C_T
○ (XM-198)	52625	4430	4	327	0.00784
△	52625	7000	4	336	0.00784

NOTES: 1. STANDARD ARMY SLING EQUIPMENT
2. TANDEM HOOK CONFIGURATION W/BARREL FORWARD

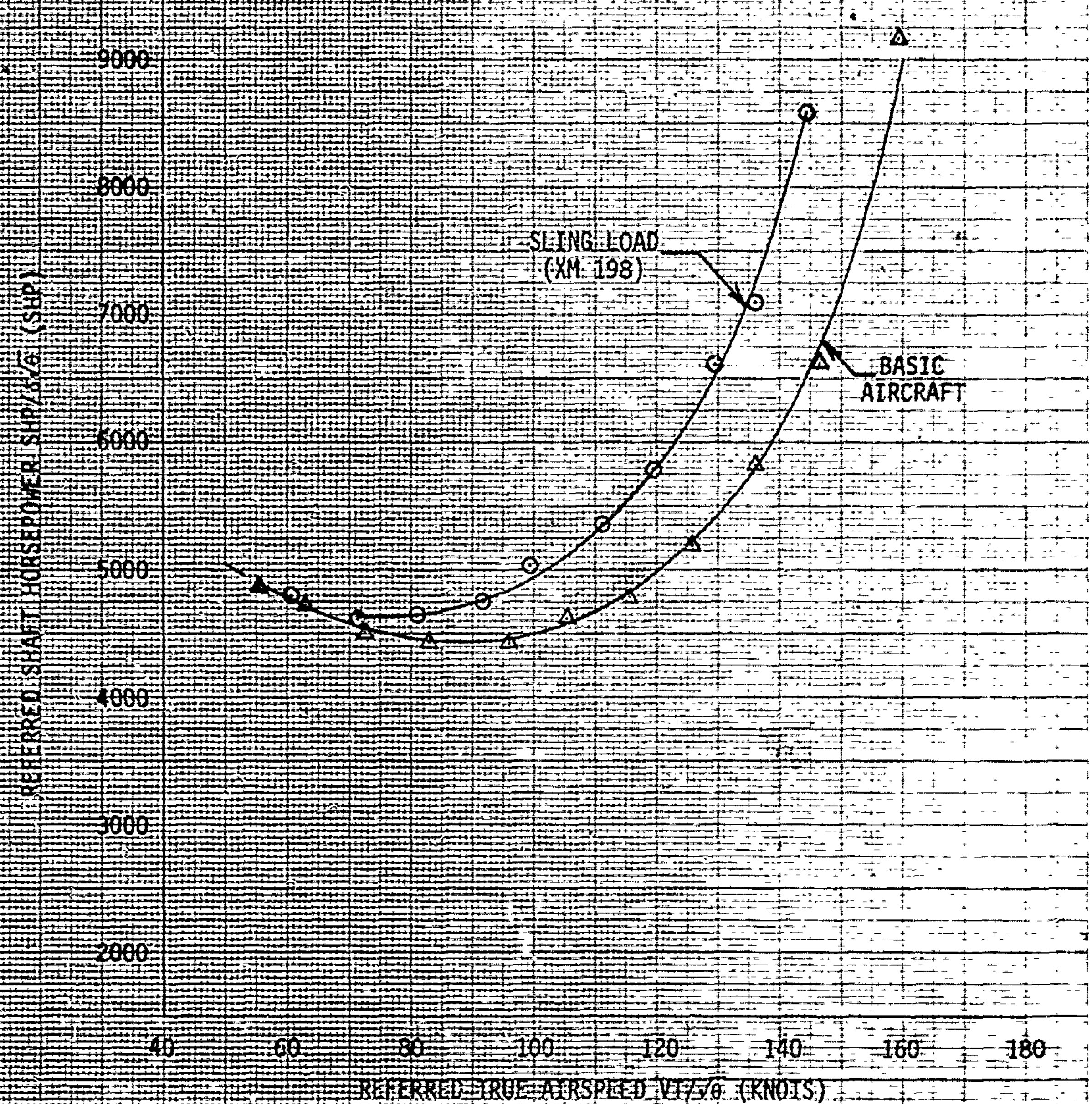


FIGURE 10
LEVEL FLIGHT PERFORMANCE
YCH-47D USA S/N 76-18479
2 POINT SLING LOAD M-198
$N/\sqrt{\theta} = 225$

SYM	AVG REF GROSS WT (LB)	AVG PRESS ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG C_T
○ (XM-198)	47011	2360	6	327	0.0070
△	47011	2200	12	336	0.0070

NOTES: 1. STANDARD ARMY SLING EQUIPMENT
2. TANDEM HOOK CONFIGURATION W/BARREL FORWARD

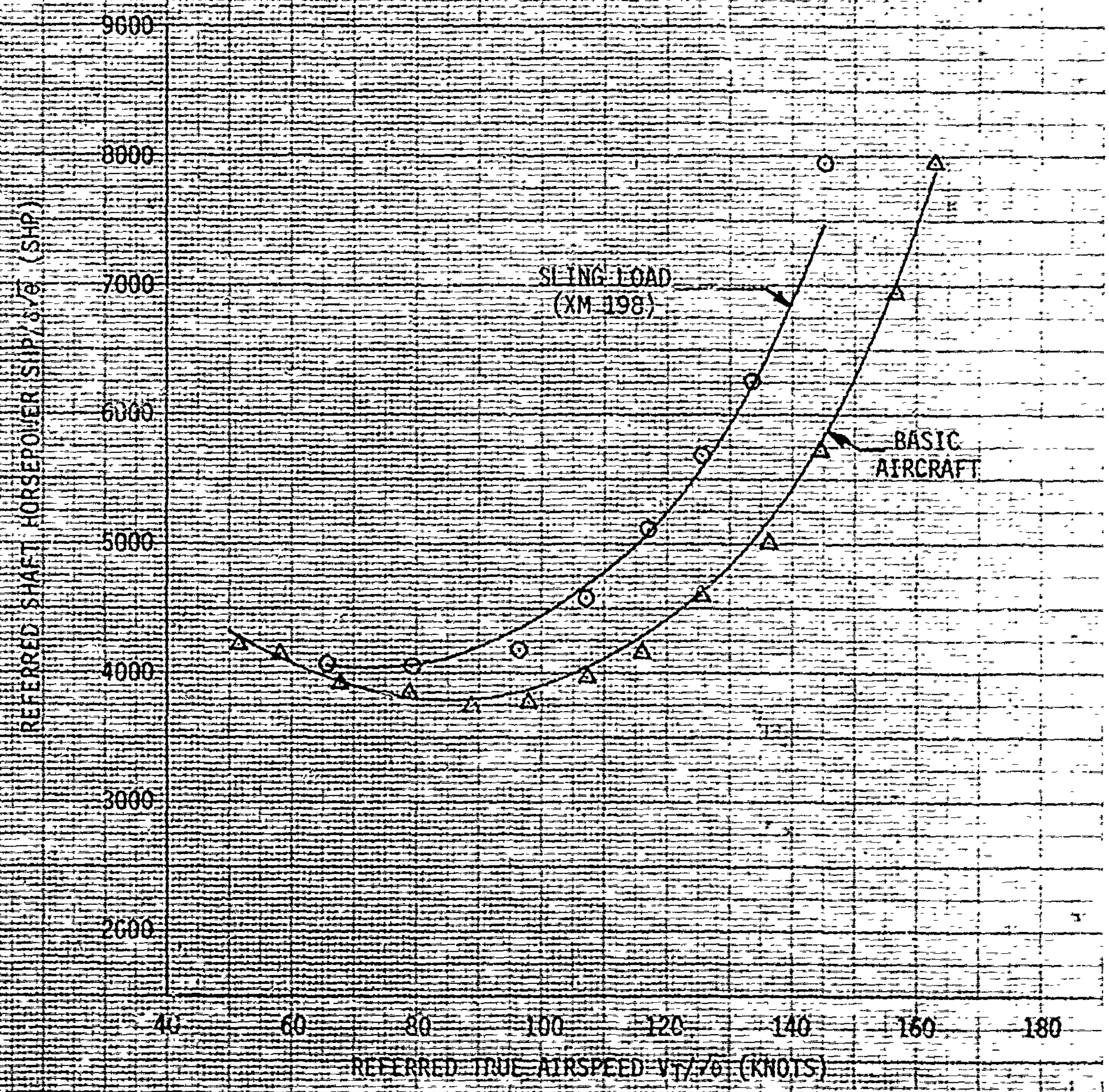
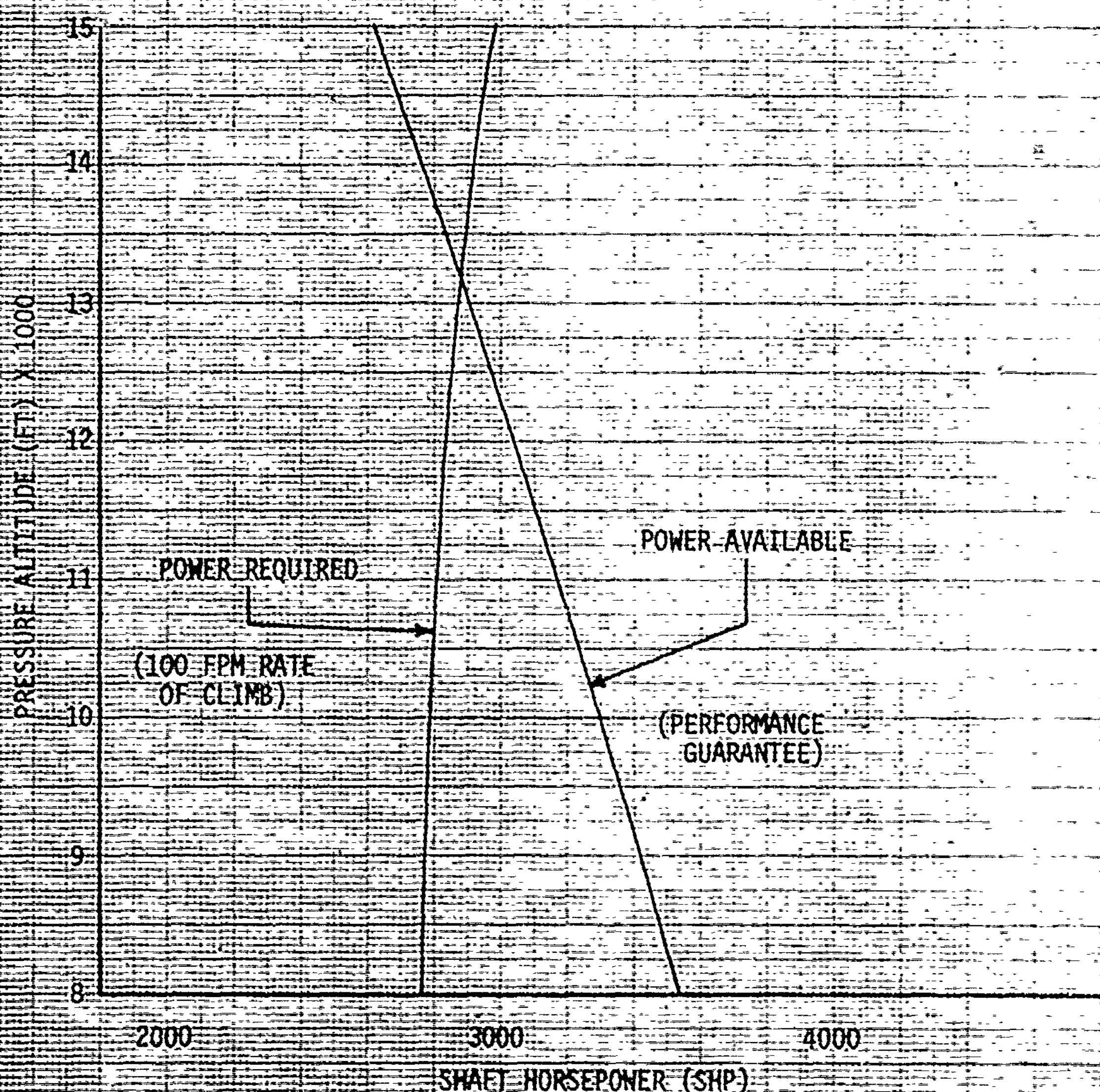


FIGURE 11
SINGLE ENGINE SERVICE CEILING
YCH-47D USA S/N 76-18749
STANDARD DAY CONDITIONS

1. POWER AVAILABLE CURVE PER LYCOMING PRIME ITEM DEVELOPMENT SPECIFICATION NO. 12953 DATED 19 NOV 1975
2. POWER REQUIRED FROM LEVEL FLIGHT PERFORMANCE DATA ($N/\sqrt{\theta} = 225$)
3. GUARANTEE GROSS WEIGHT 33,000 LB



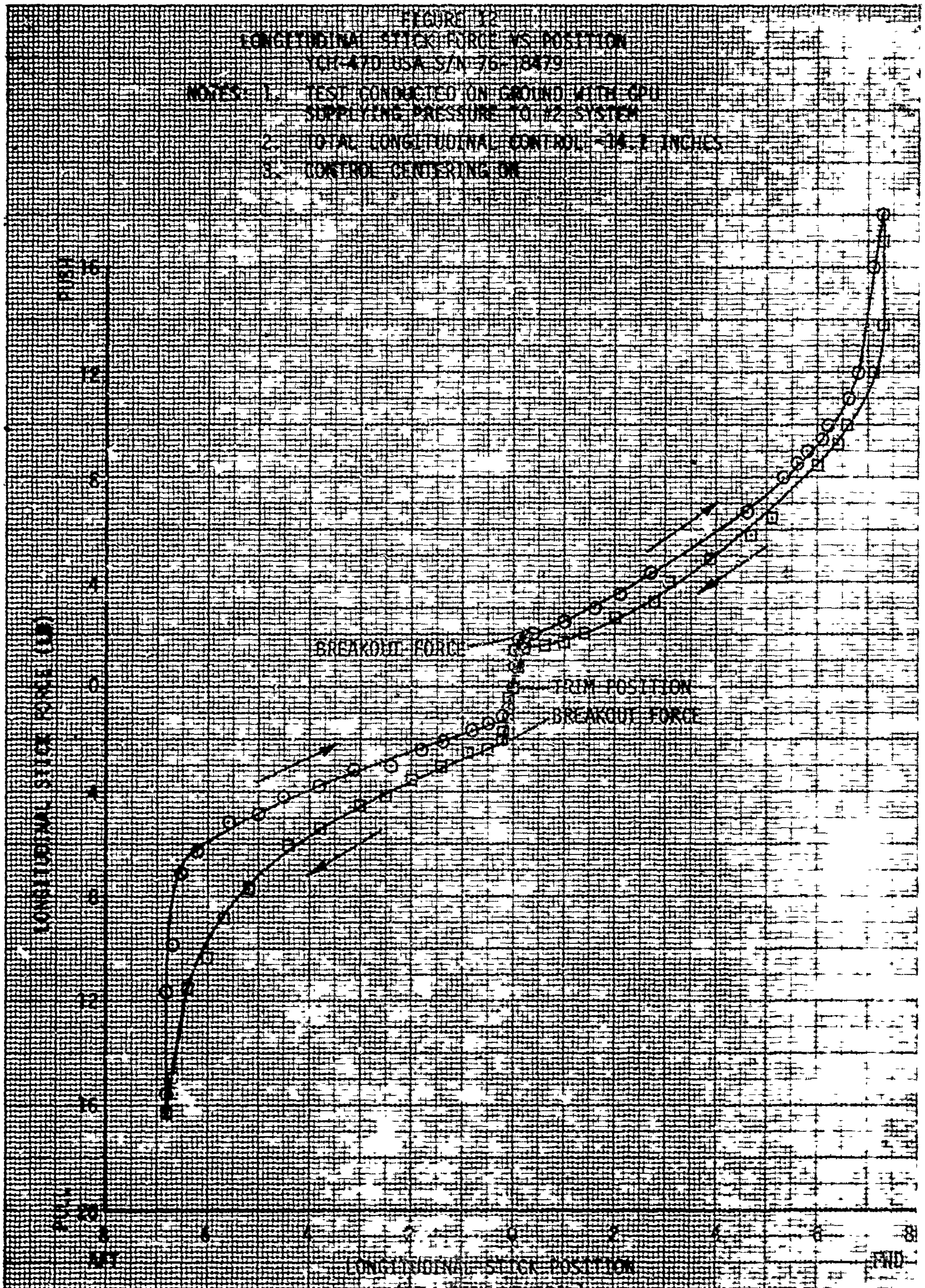


FIGURE 12
LONGITUDINAL STICK FORCE VS POSITION
YCH-47D USA S/N 76-18479
NOTES: 1. TEST CONDUCTED ON GROUND WITH GPU SUPPLYING PRESSURE TO #2 SYSTEM
2. TOTAL LONGITUDINAL CONTROL = 14.2 INCHES
3. CONTROL CENTERING ON
BREAKOUT FORCE
TRIM POSITION
BREAKOUT FORCE
LONGITUDINAL STICK FORCE (LB)
PUSH
PULL
16
12
8
4
0
4
8
12
16
20
8
6
4
2
0
2
4
6
8
AFT
FWD
LONGITUDINAL STICK POSITION
(IN. FROM NEUTRAL)

LATERAL STICK FORCE VS POSITION
YCH-47D USA S/N 76-18479

NOTES: 1. TEST CONDUCTED ON GROUND WITH GPU SUPPLYING PRESSURE TO #2 SYSTEM
2. TOTAL LATERAL CONTROL = 9.7 INCHES
3. CONTROL CENTERING ON

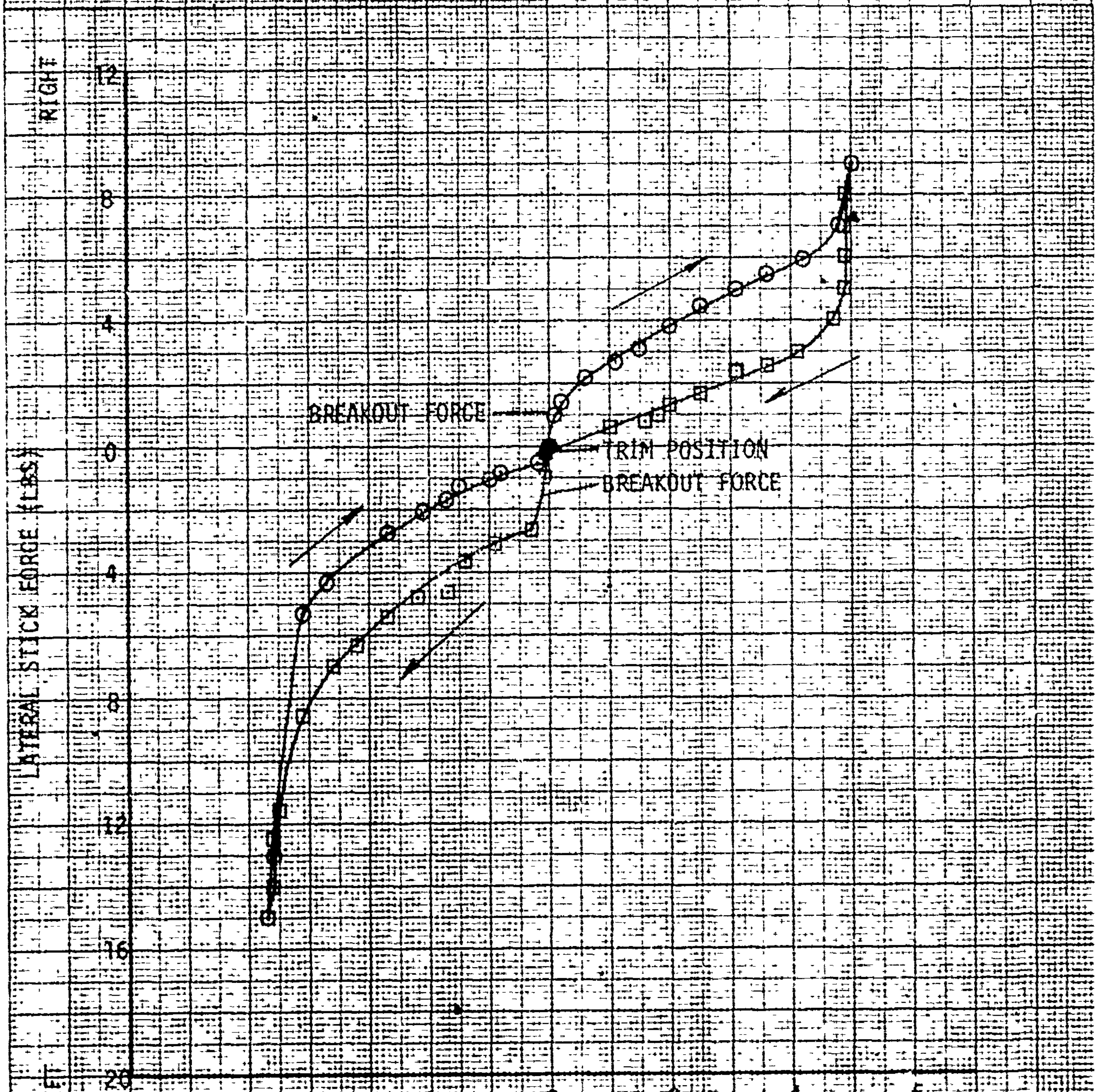


FIGURE 14
DIRECTIONAL PEDAL FORCE VS POSITION
YCH-47D USA S/N 76-18479

NOTES: 1. TEST CONDUCTED ON GROUND WITH GPU SUPPLYING PRESSURE TO #2 SYSTEM.
2. TOTAL DIRECTIONAL CONTROL TRAVEL = 9.2 INCHES
3. CONTROL CENTERING ON

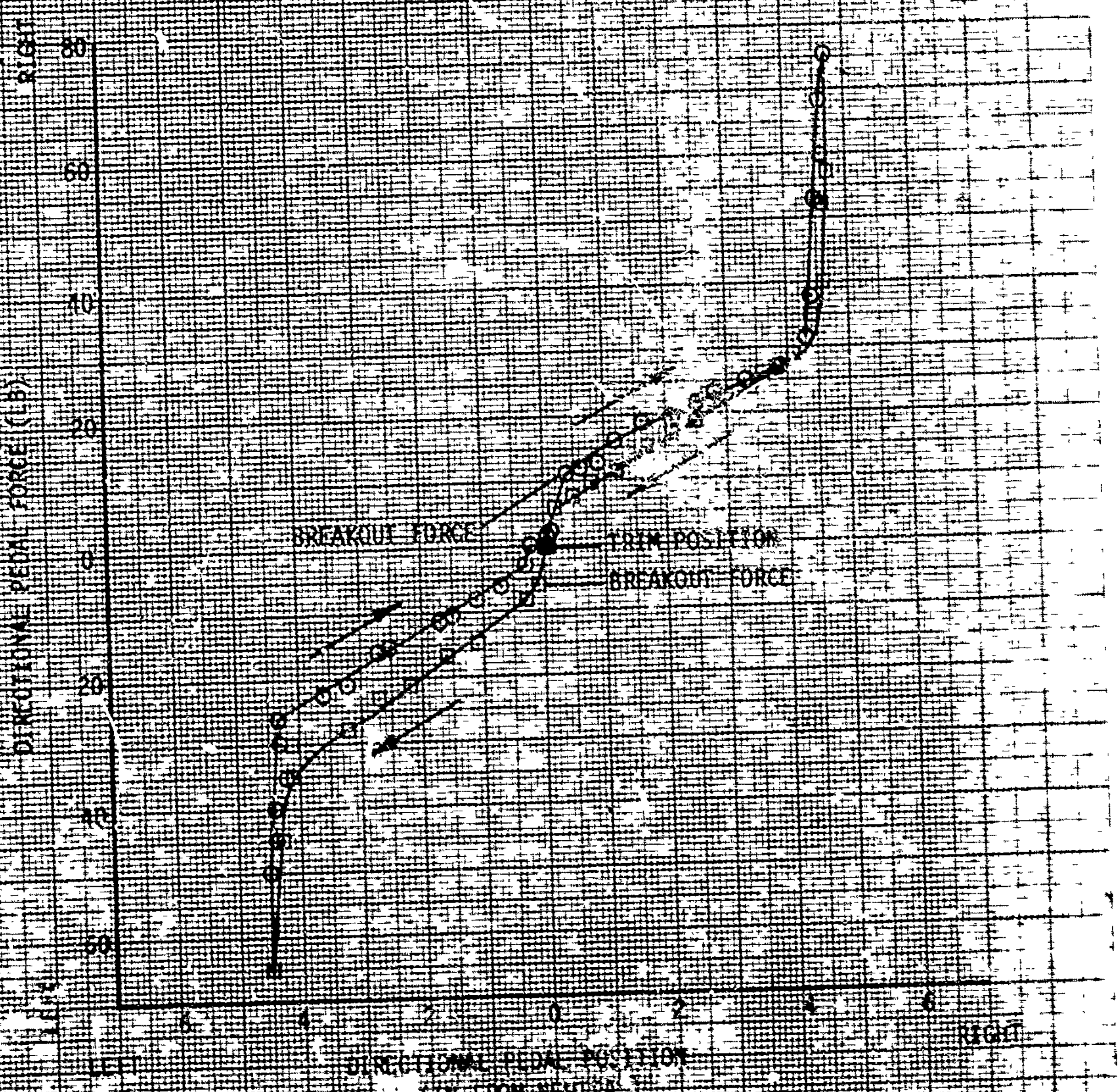


FIGURE 18
COLLECTIVE STICK FORCE VS POSITION
YCH-47D USA S/N 76-18479

NOTES: 1. TEST CONDUCTED ON GROUND WITH GPU SUPPLYING PRESSURE TO #2 SYSTEM.
2. TOTAL COLLECTIVE CONTROL TRAVEL = 8.6 INCHES
3. THRUST CONTROL ROD MAGNETIC BRAKE SWITCH DEPRESSED.

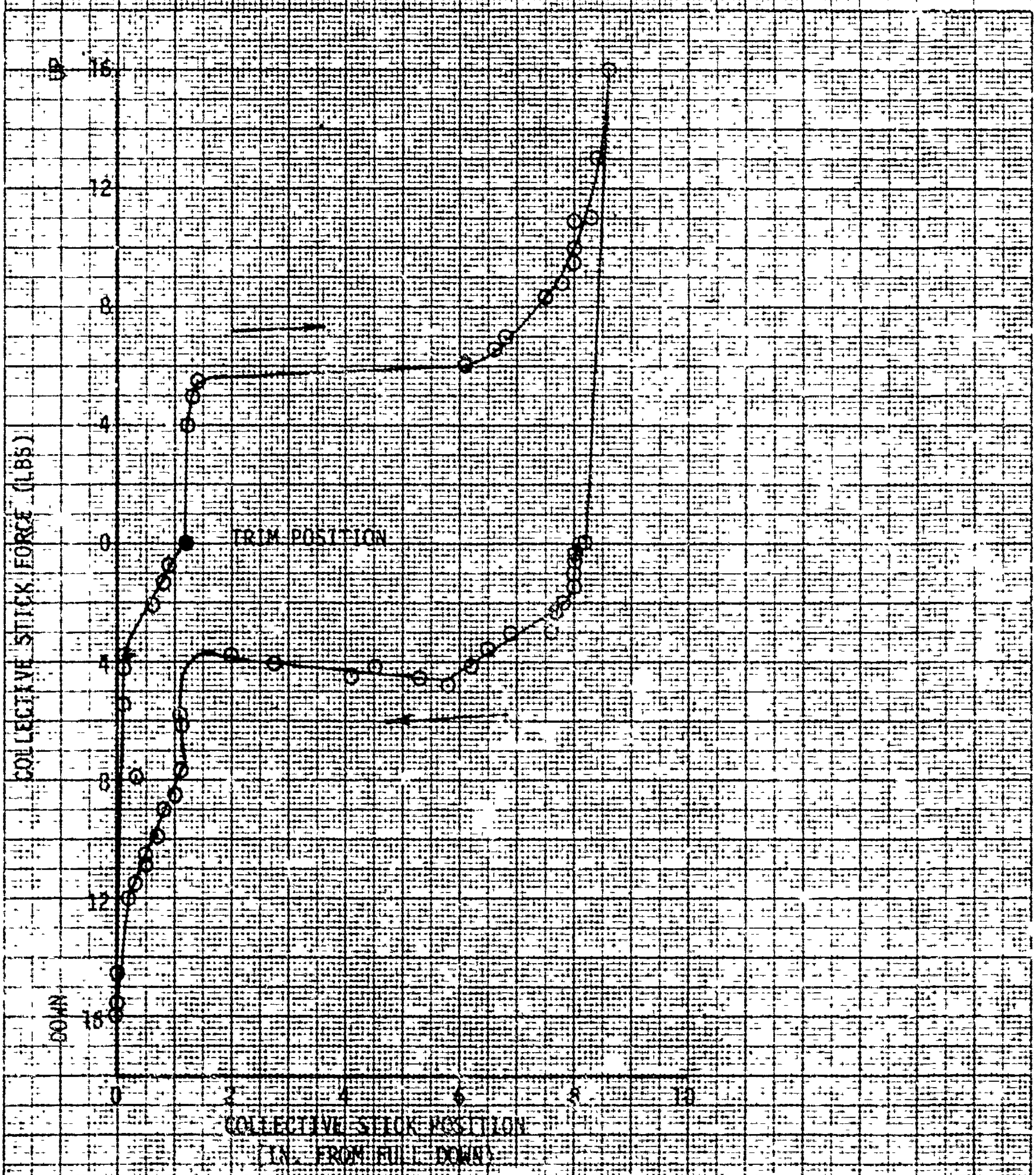


FIGURE 16
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
YCH-47D USA S/N 76-18479

AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN. FS.)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)
30,580	327	2480	12	223

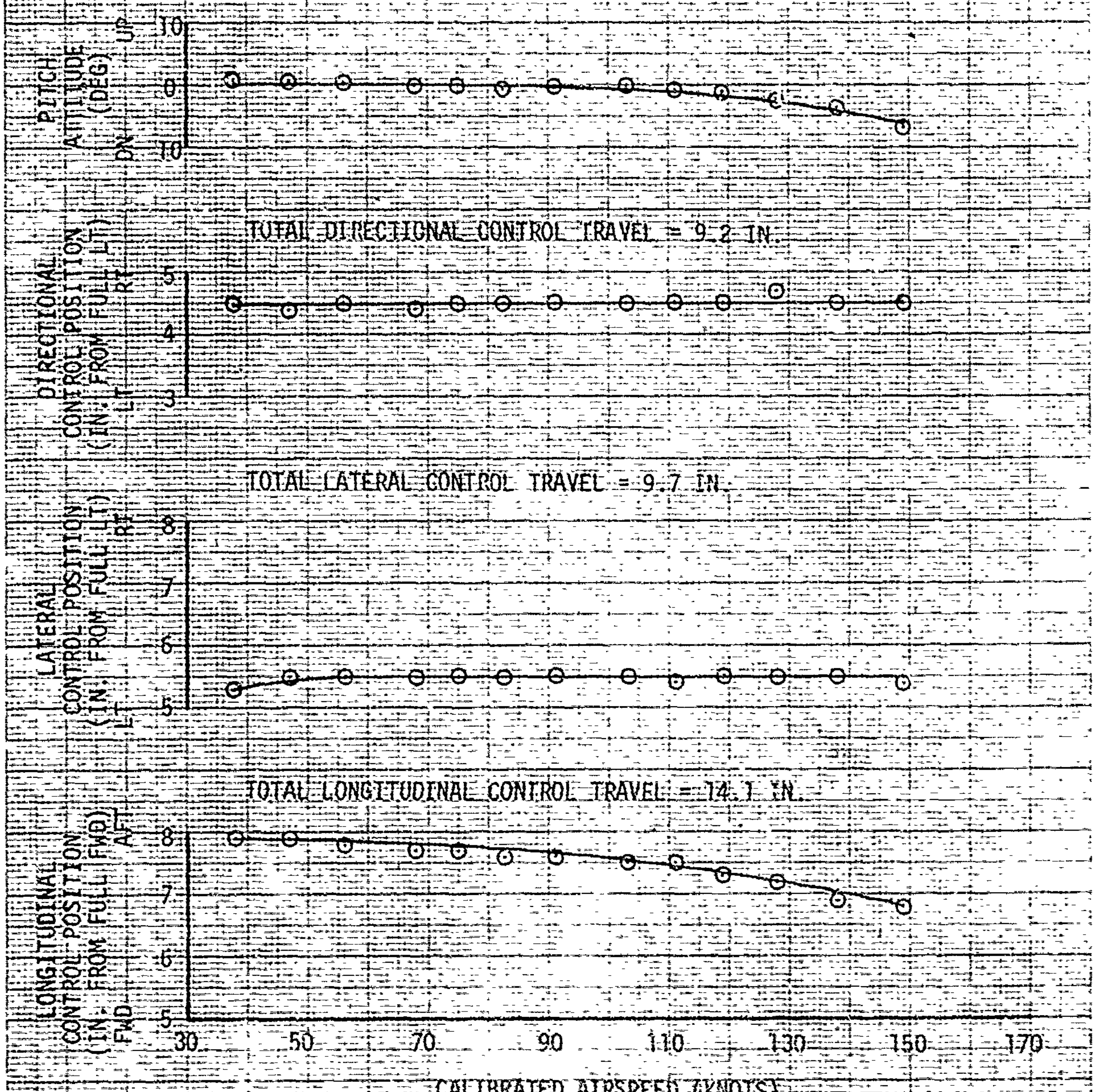


FIGURE 17
CONTROL POSITIONS IN TRIMMED FORWARD FLIGHT
YCH-47D USA S/N 76-18479

AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN. FS.)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)
42,760	336	9860	2.4	220

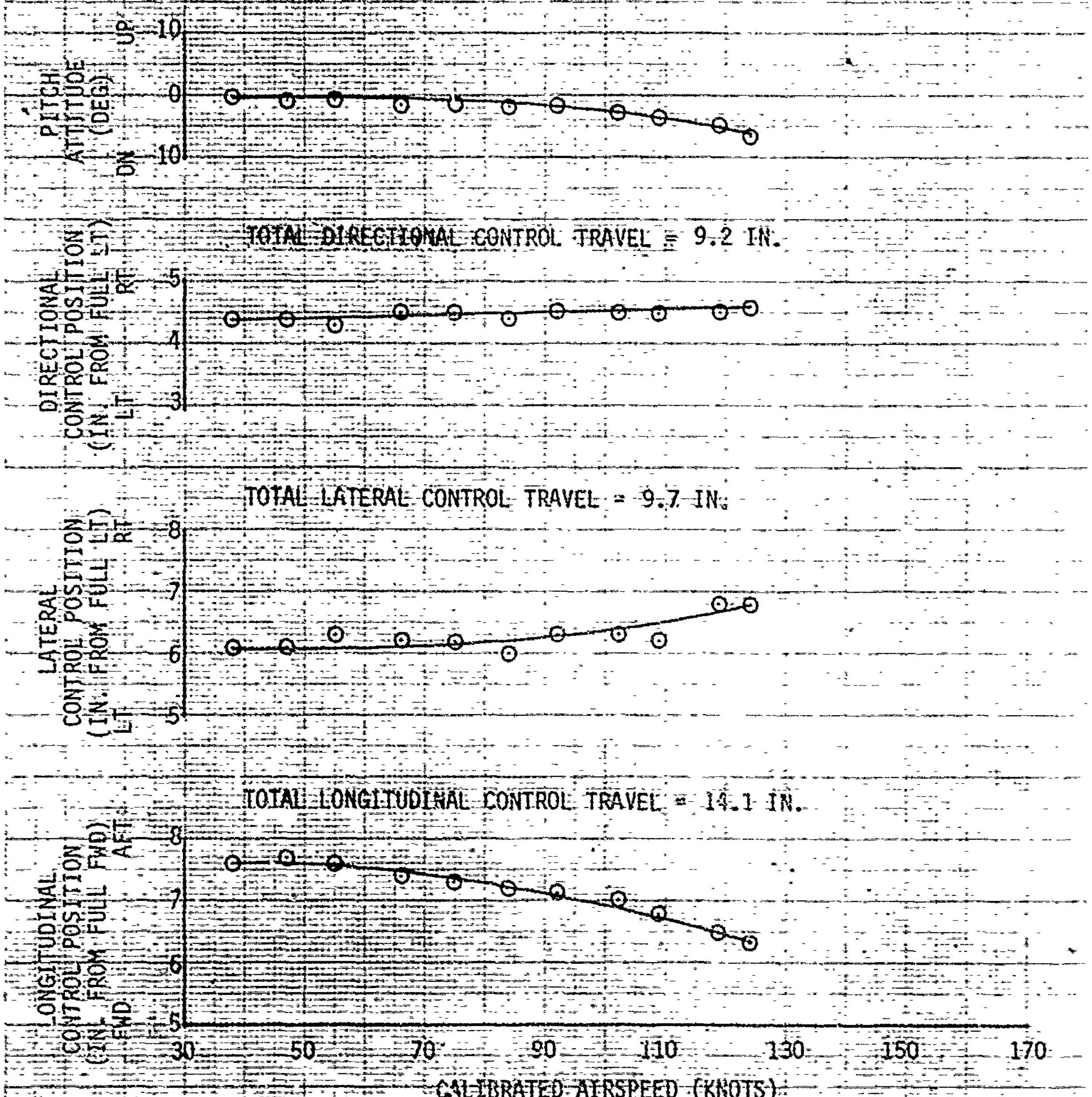


FIGURE 18
STATIC LONGITUDINAL STABILITY
YCH-47D USA S/N 76-18979
LEVEL FLIGHT

SYMBOL	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN. FS.)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM A/S (KCAS)
⊙	30800	329.9	5000	7	225	66
⊡	29300	330.1	5000	9	225	118

NOTE: SHADED POINTS DENOTE TRIM

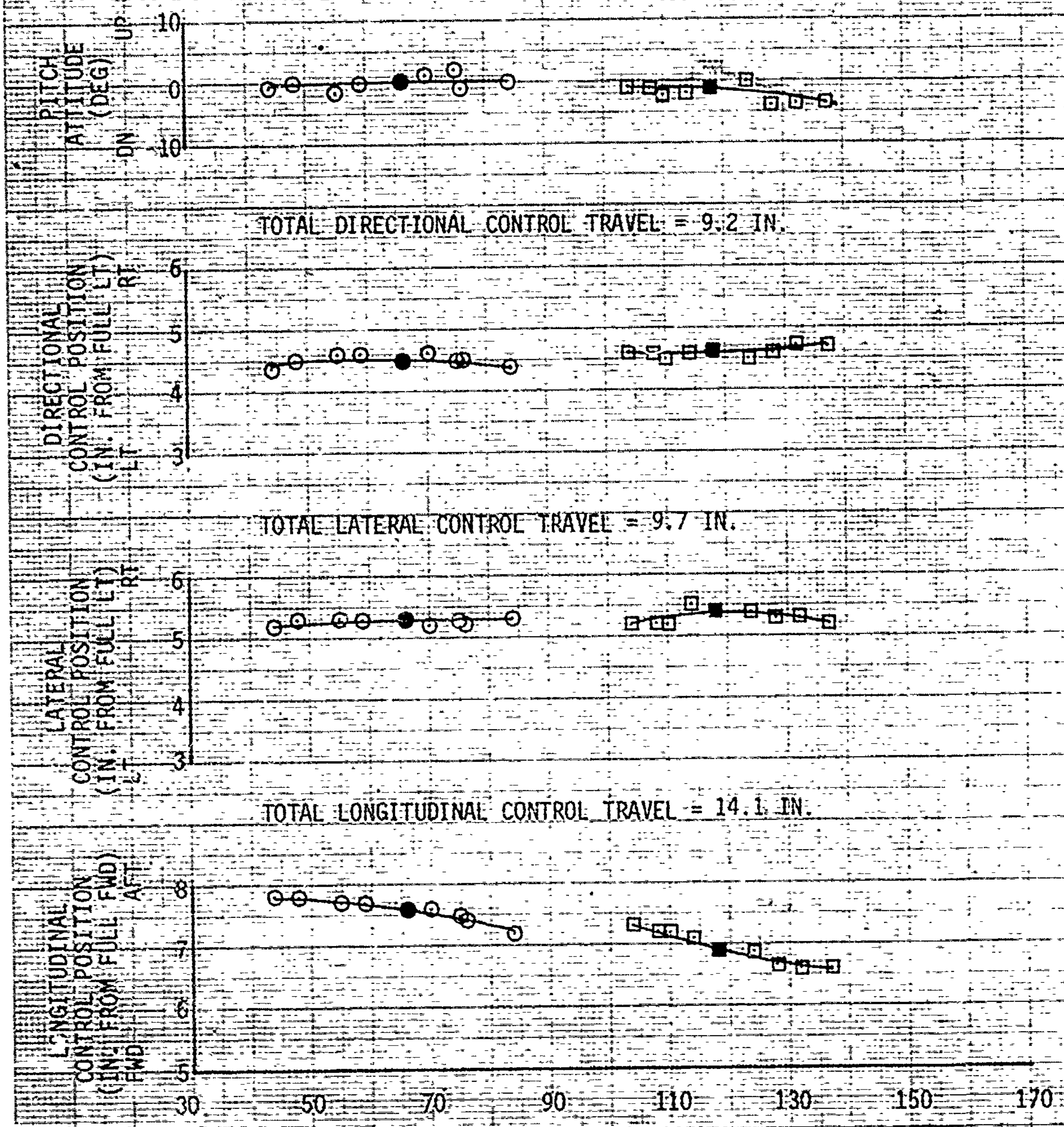


FIGURE 19
STATIC LONGITUDINAL STABILITY
YCH-47D USA S/N 70-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN. FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
47540	331.5	5000	7	225	64
46540	331.8	5000	7	225	124

NOTE: SHADED POINTS DENOTE TRIM

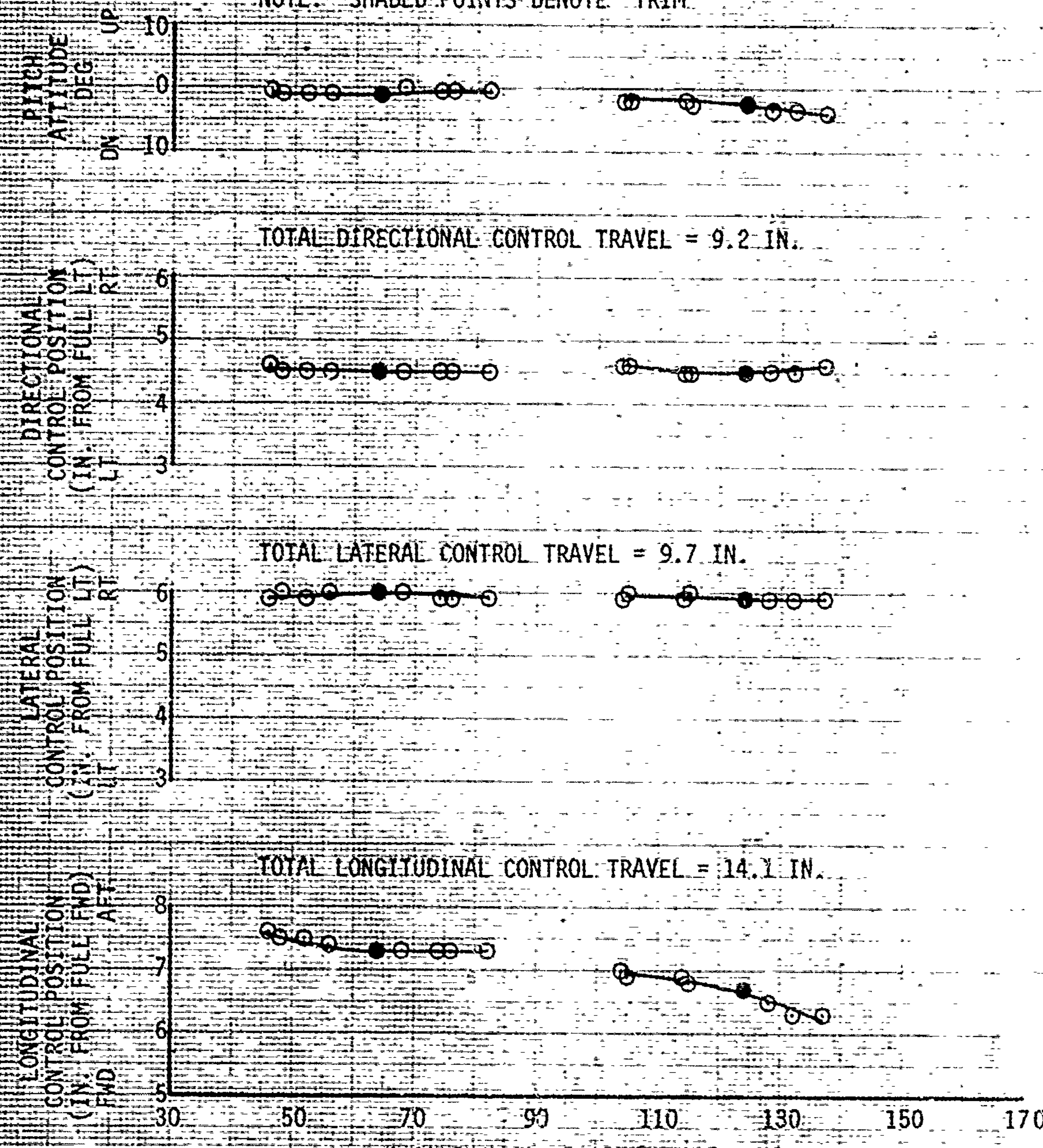


FIGURE 20
STATIC LATERAL DIRECTIONAL STABILITY
YCH-47D USA S/N 76-18479

FLIGHT CONDITION	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN. FS.)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM A/S (KCAS)
LEVEL FLT	31000	329.7	5000	7	225	67

NOTE: SHADED POINTS DENOTE TRIM

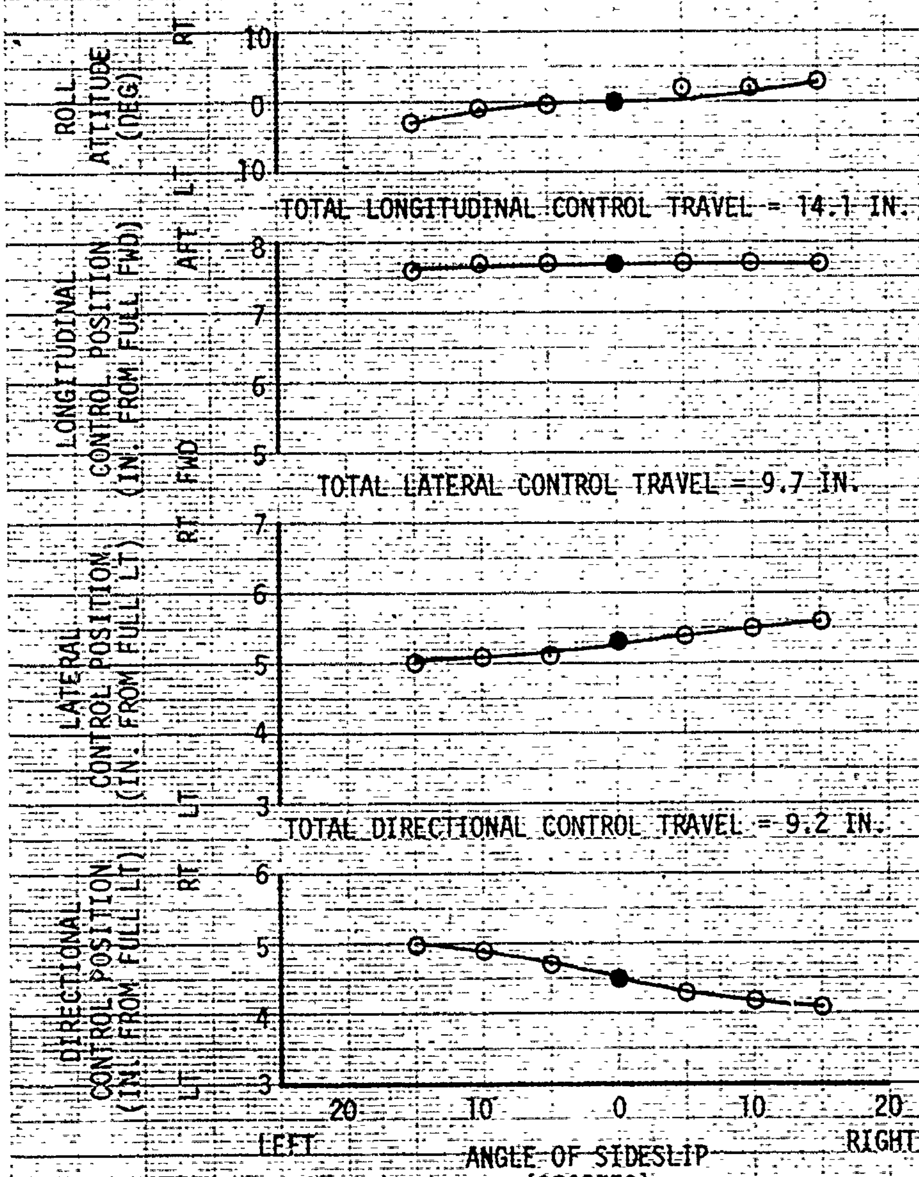


FIGURE 21
STATIC LATERAL-DIRECTIONAL STABILITY
YCH-47D USA S/N 76-18479

FLIGHT CONDITION	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN. FS.)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM A/S (KCAS)
LEVEL FLT	30,000	330.1	5000	8	225	120

NOTE: SHADED POINTS DENOTE TRIM

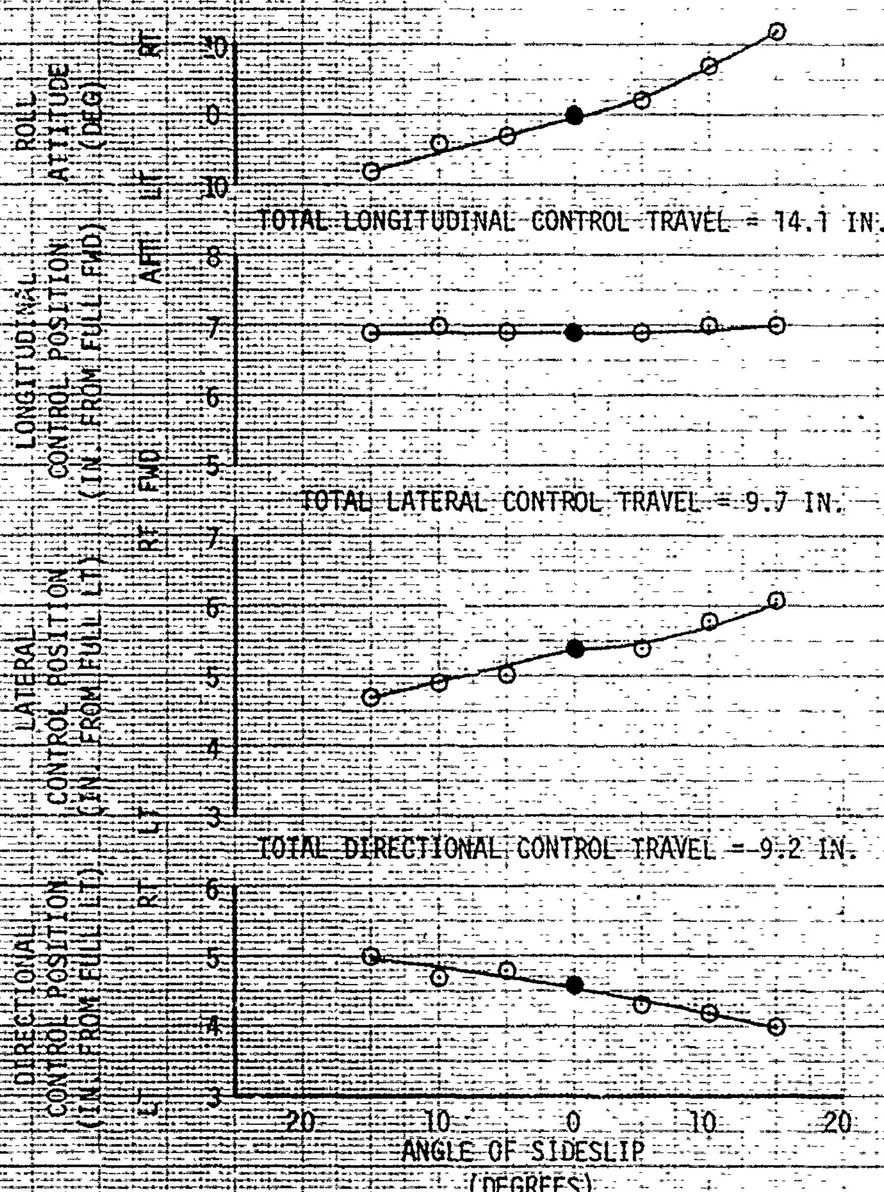


FIGURE 22
STATIC LATERAL-DIRECTIONAL STABILITY
YCH-47D USA S/N 76-18479

FLIGHT CONDITION	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN. FS)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM A/S (KCAS)
LEVEL FLT	48240	331.3	5000	7	225	64

NOTE: SHADED POINTS DENOTE TRIM

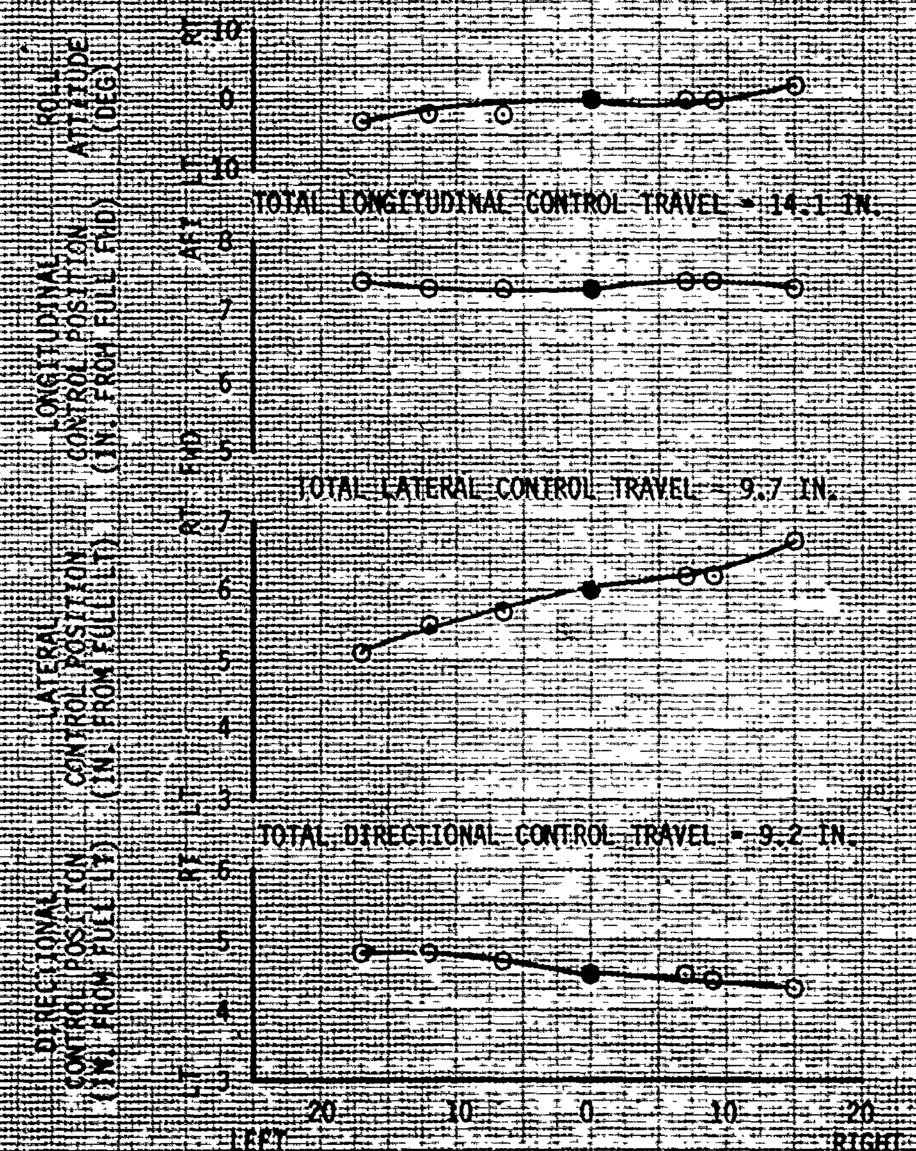


FIGURE 23
STATIC LATERAL DIRECTIONAL STABILITY
YCH-47D USA S/N 76-18479

FLIGHT CONDITION	AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN. FS)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
LEVEL FLT	45940	332	5000	7	225	119

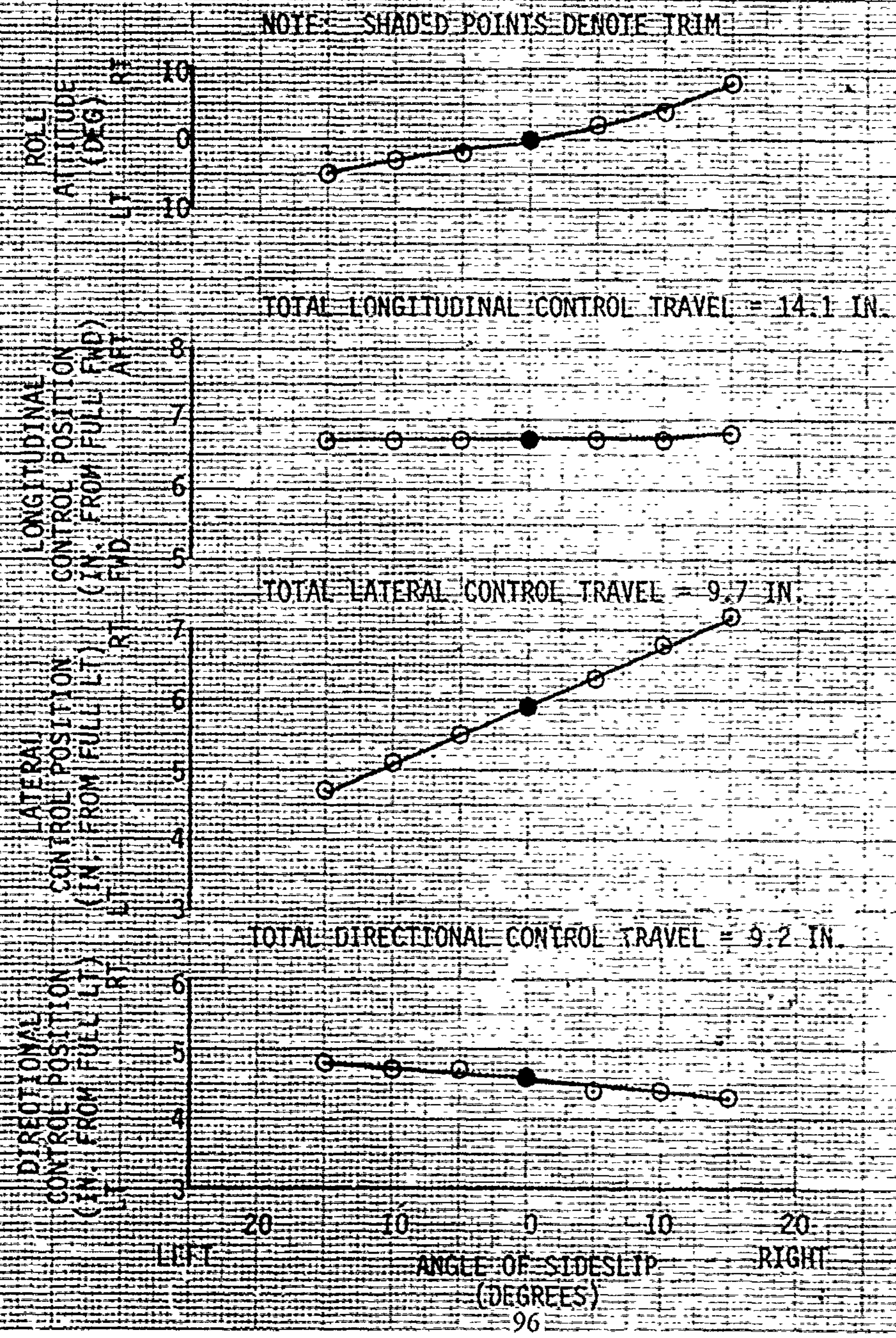


FIGURE 24
MANEUVERING STABILITY
YCH-47D USA S/N 76-18479

AVG GROSS WEIGHT (LB)	AVG CG LOCATION (IN. FS)	AVG DENSITY ALT (FT)	AVG OAT (°C)	AVG ROTOR SPEED (RPM)	TRIM A/S (KCAS)
29,600	331.2	5000	9	225	121

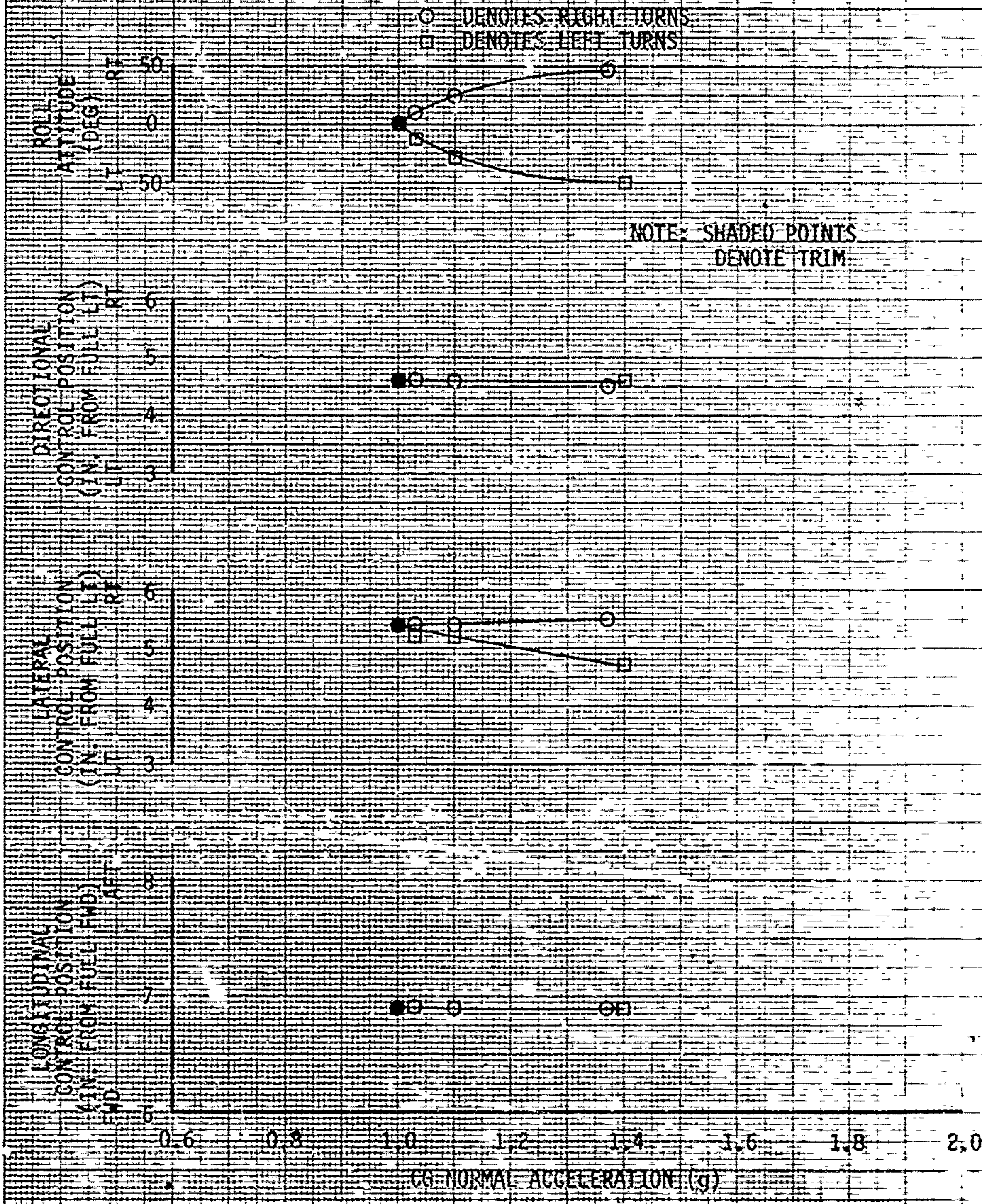


FIGURE 25
SHORT PERIOD TIME HISTORY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
30,360	5000	8	329.9	225	121

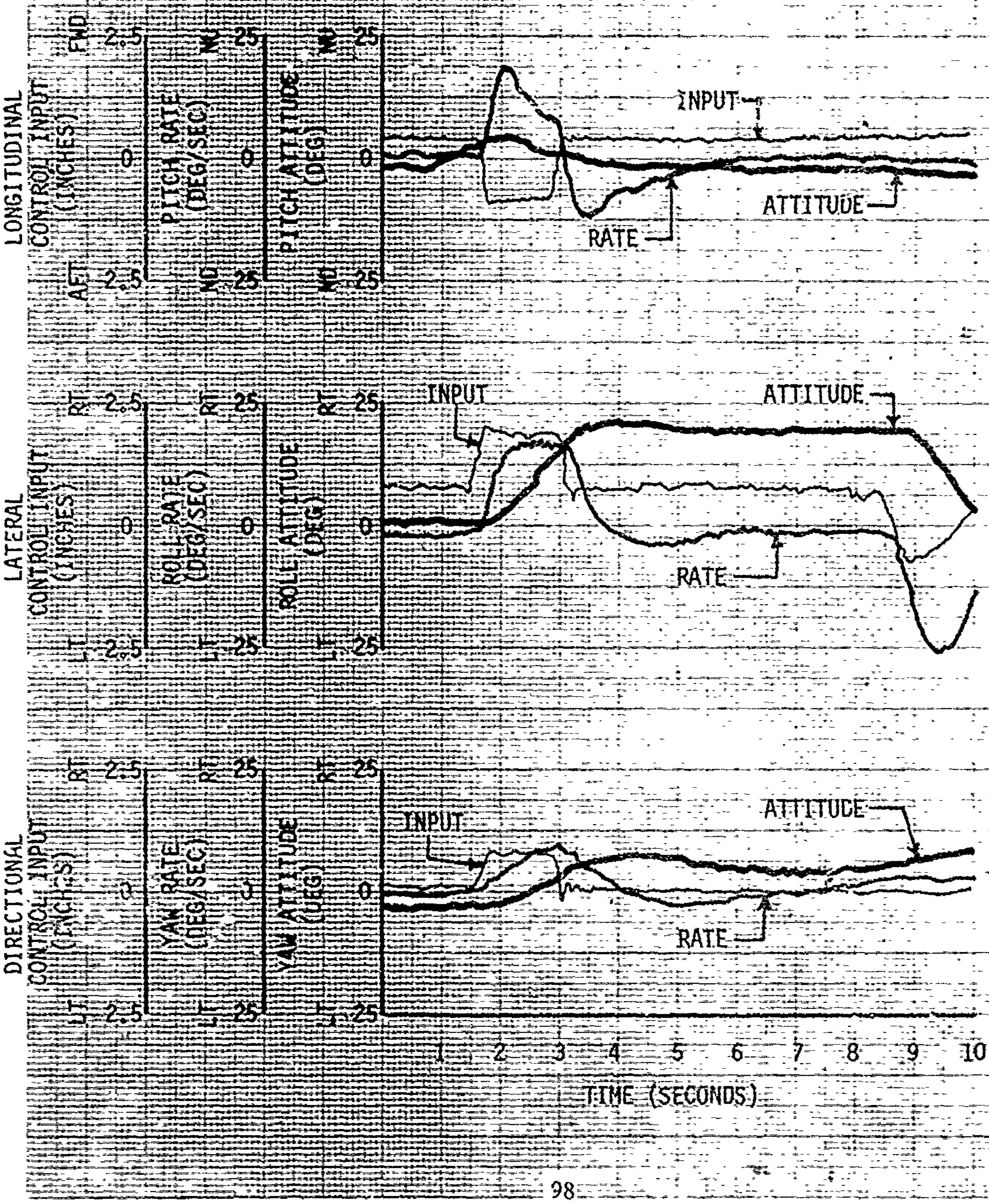


FIGURE 26
LONGITUDINAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
HOVER

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)
32,560	-1000	6	328.9	225

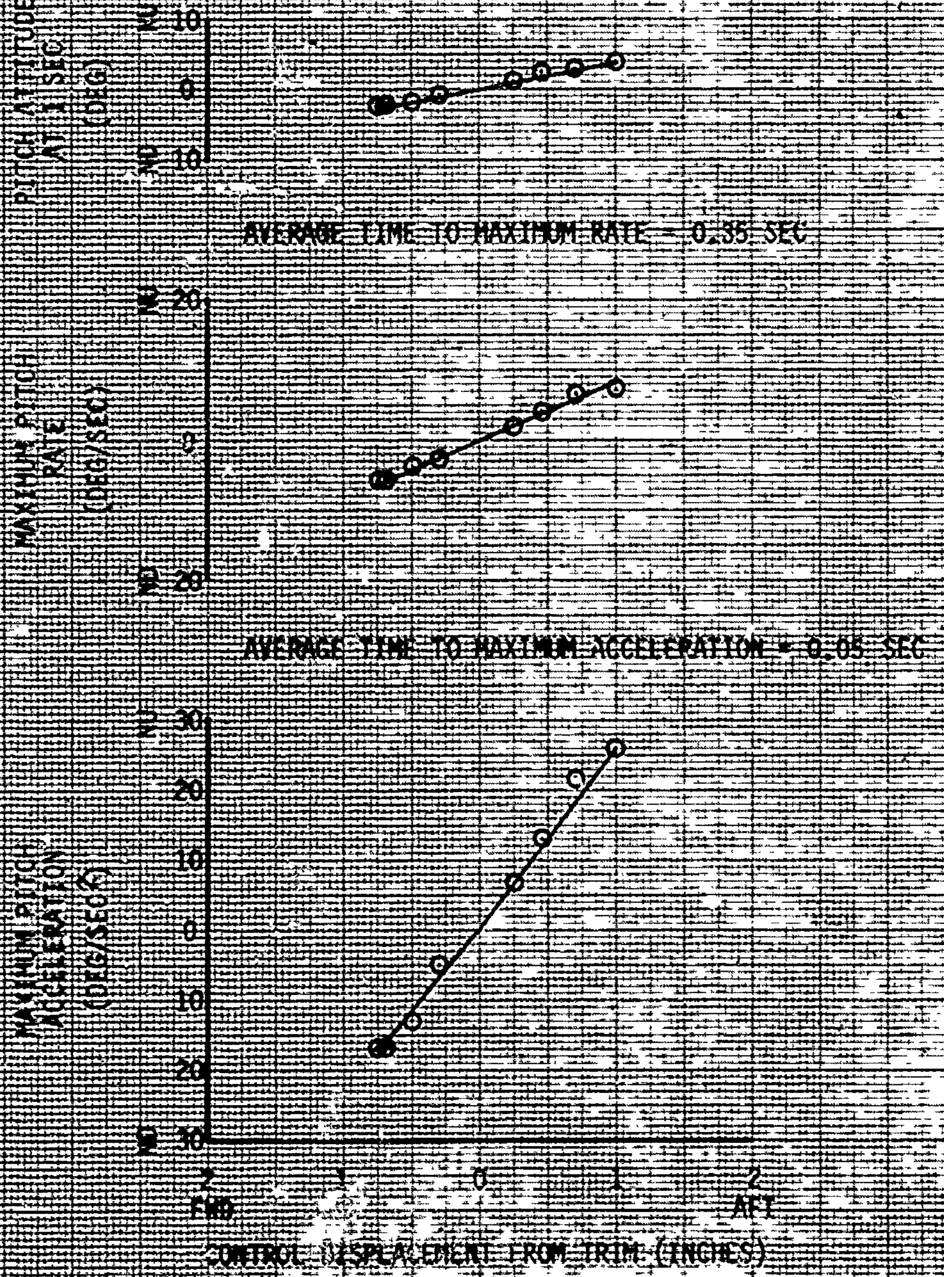


FIGURE 27
LONGITUDINAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
31,900	5000	7	329.2	225	65

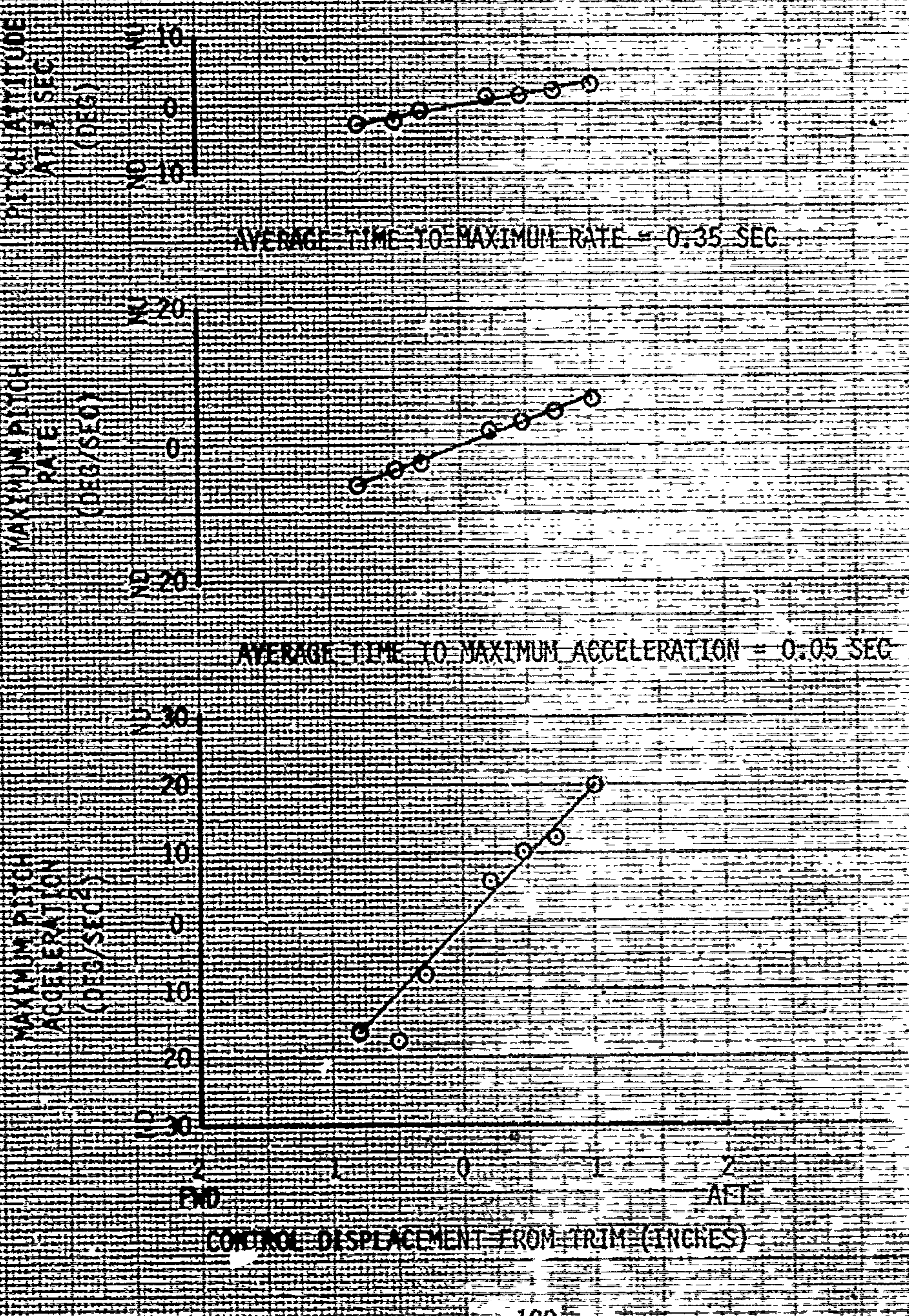


FIGURE 28
LONGITUDINAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
30,360	5000	8	329.9	225	121

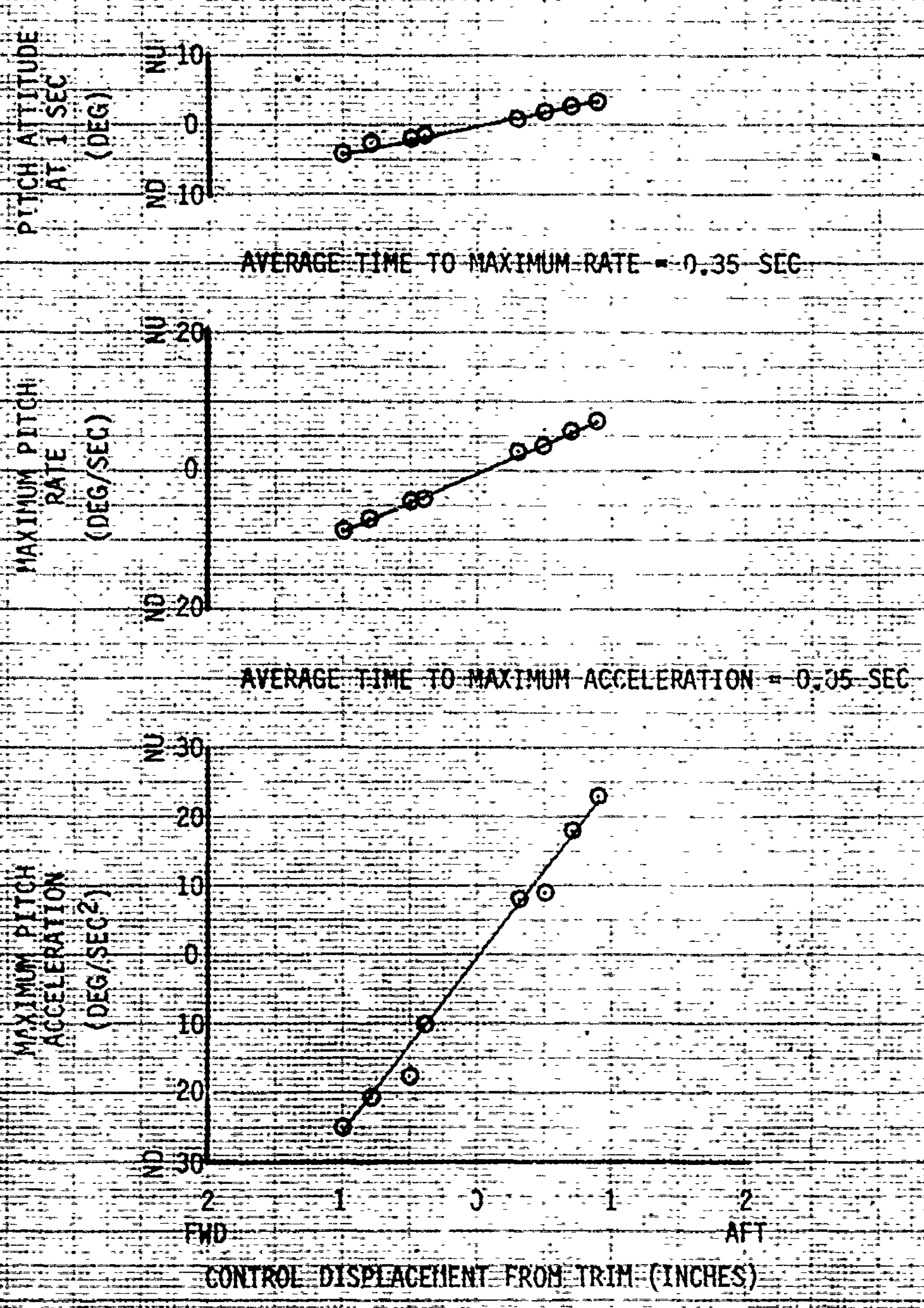


FIGURE 29
LONGITUDINAL CONTROLLABILITY
YCH-47D USA S/N 76-13479
HOVER

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)
51660	-700	9	330.3	225

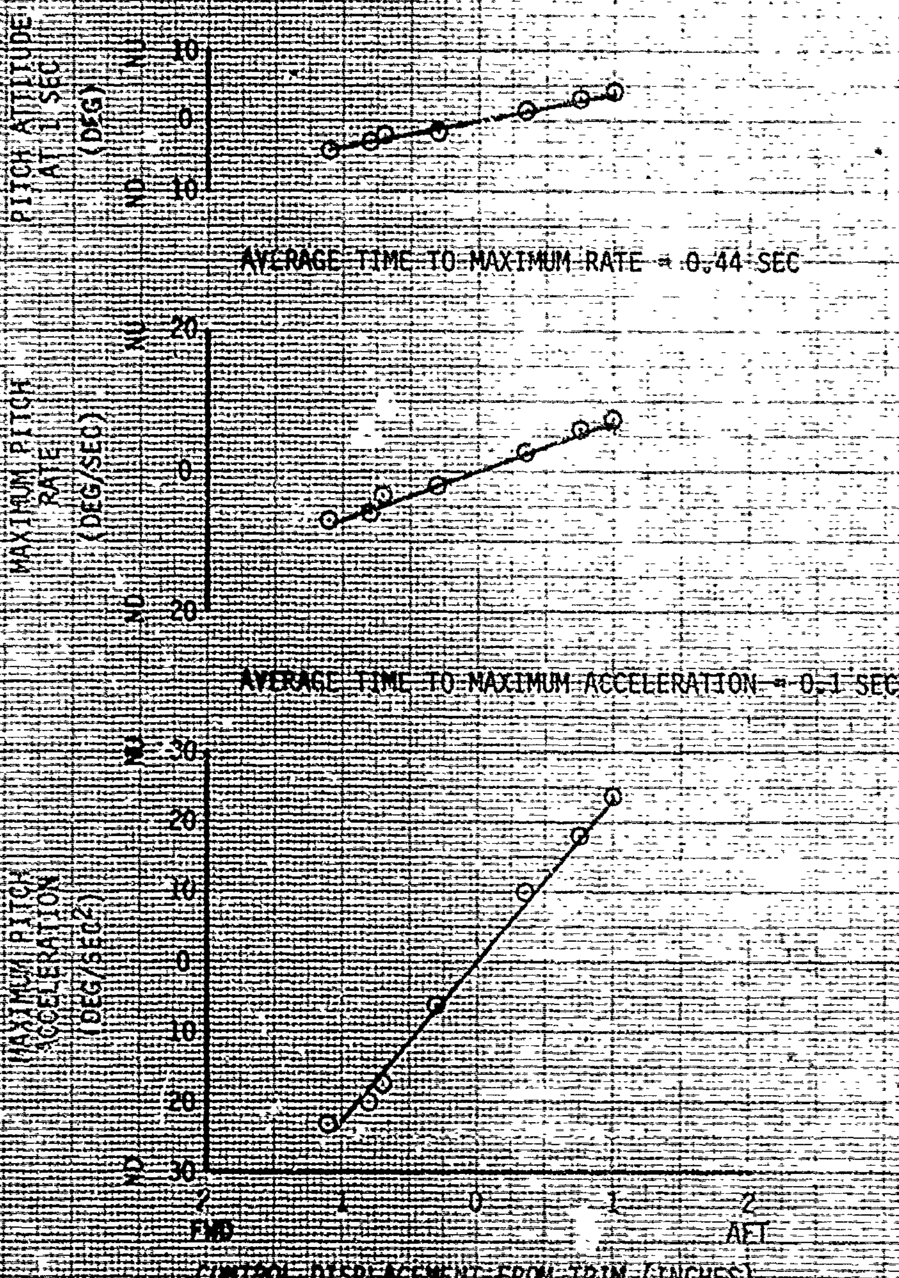


FIGURE 30
LONGITUDINAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
49880	5000	7	330.8	225	65

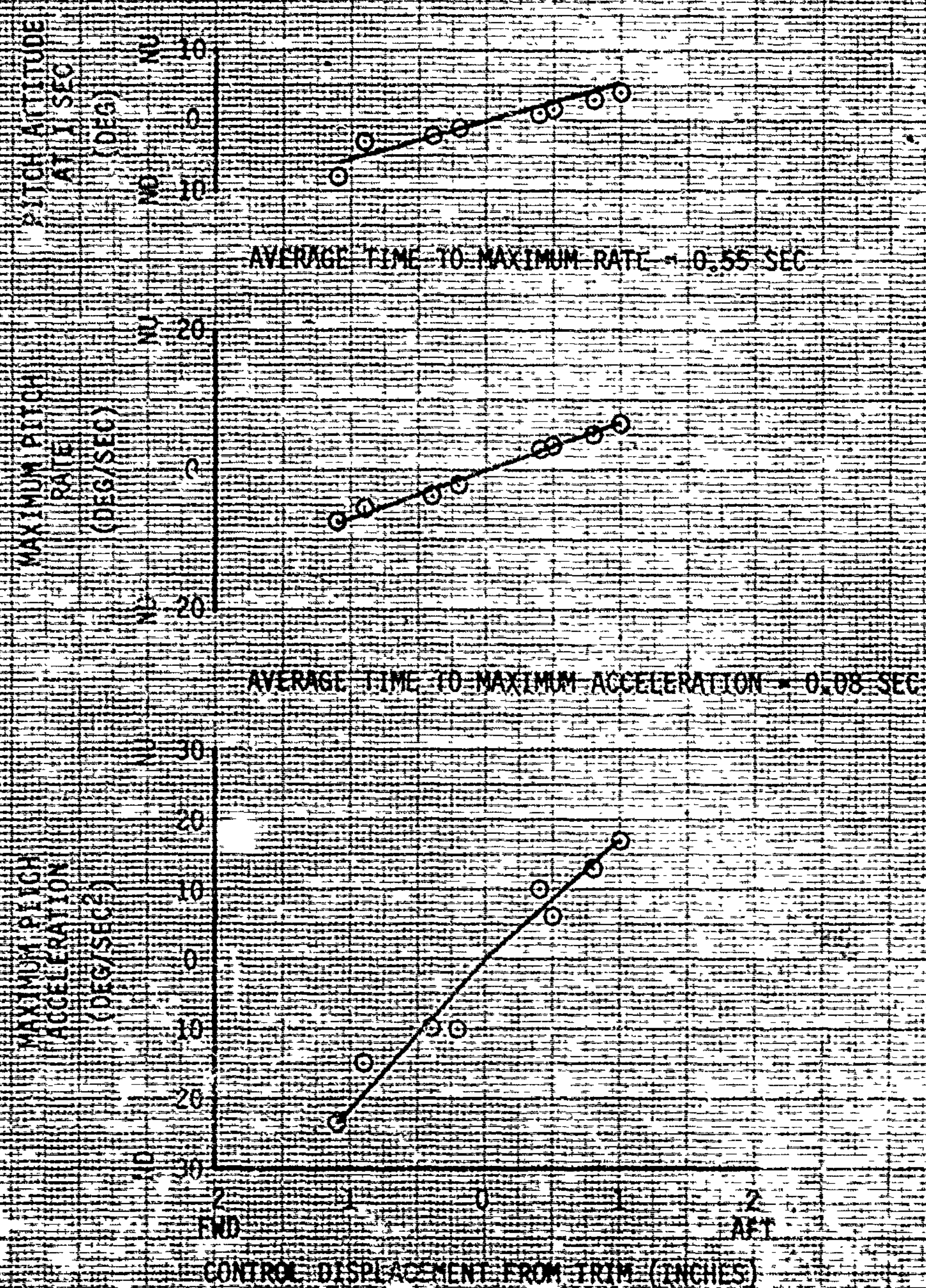


FIGURE 31
LONGITUDINAL CONTROLLABILITY
CH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
50680	5000	-10	330.6	225	121

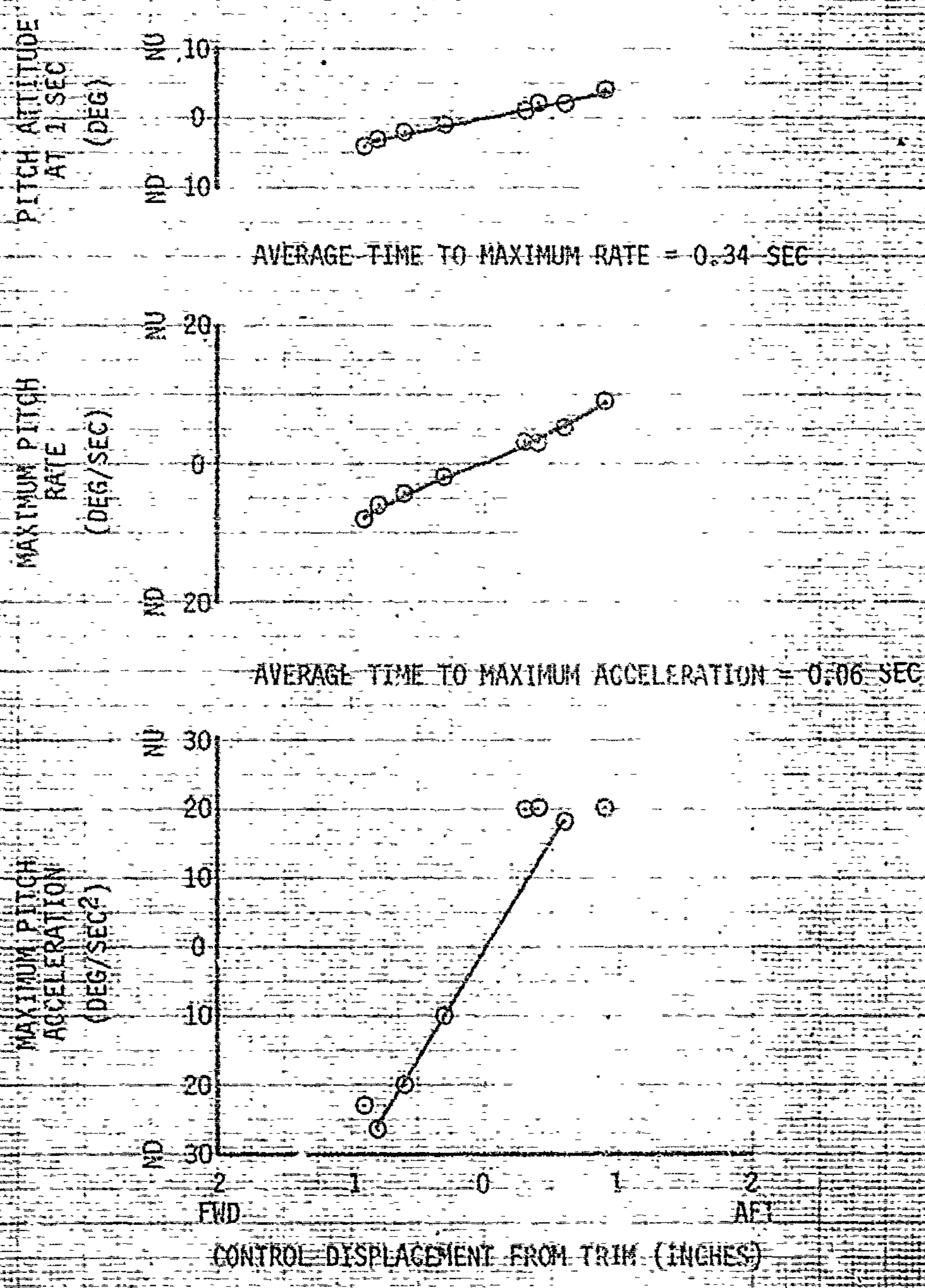


FIGURE 32
LONGITUDINAL AIRCRAFT RESPONSE
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
30,360	5000	8	329.9	225	121

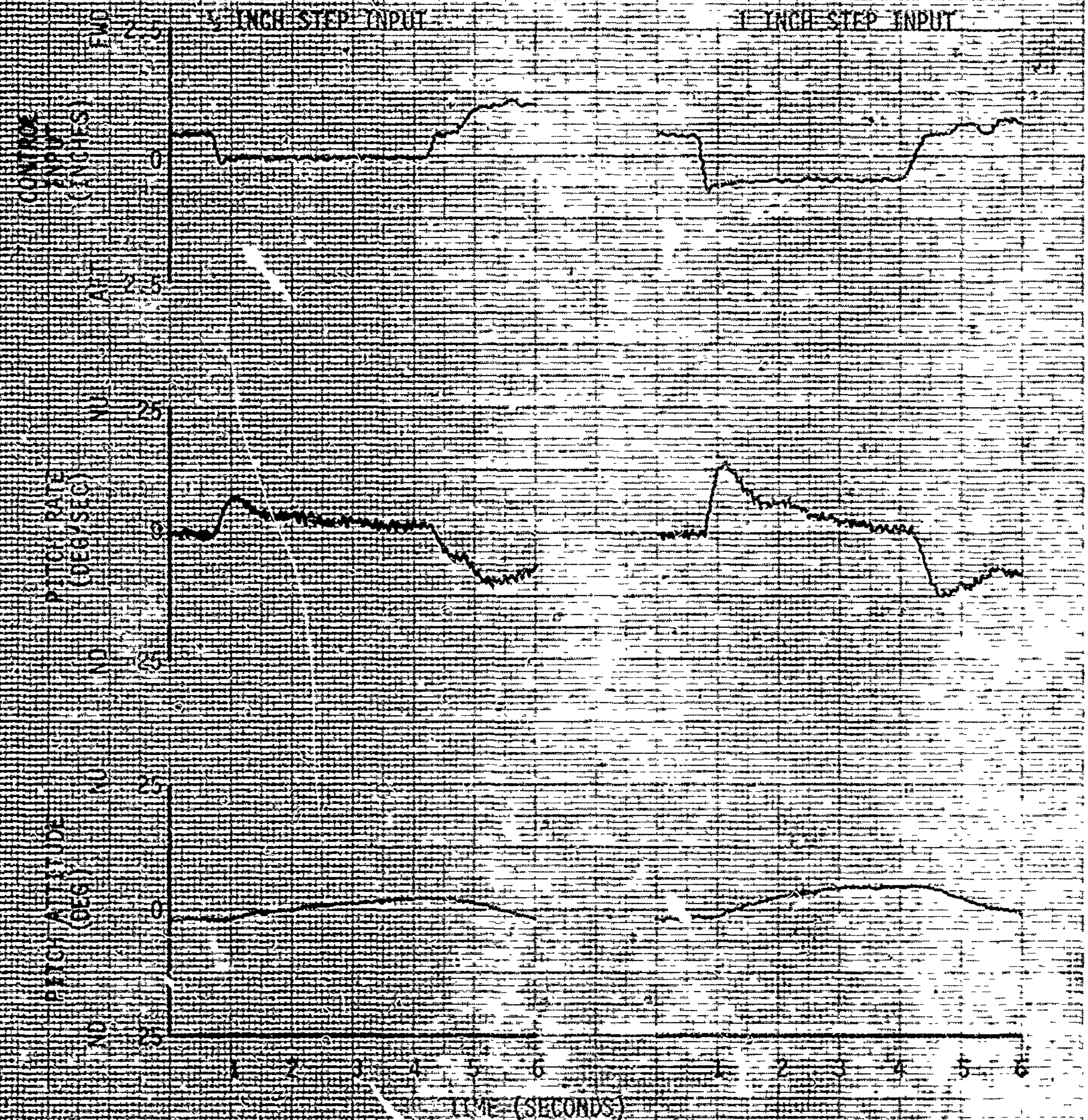


FIGURE 33
LATERAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
HOVER

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)
32,560	1000	6	328.9	225

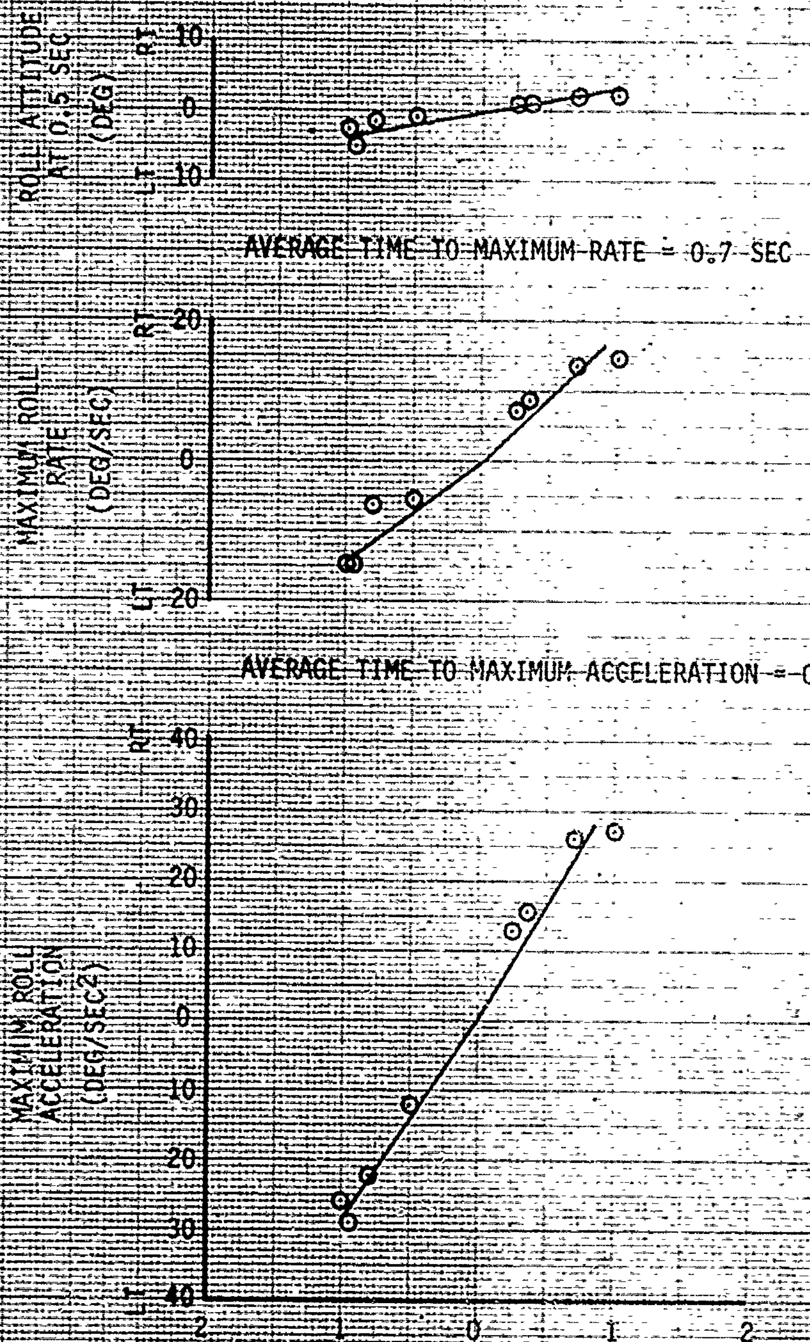


FIGURE 34
LATERAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
31,900	5000	7	329.2	225	65

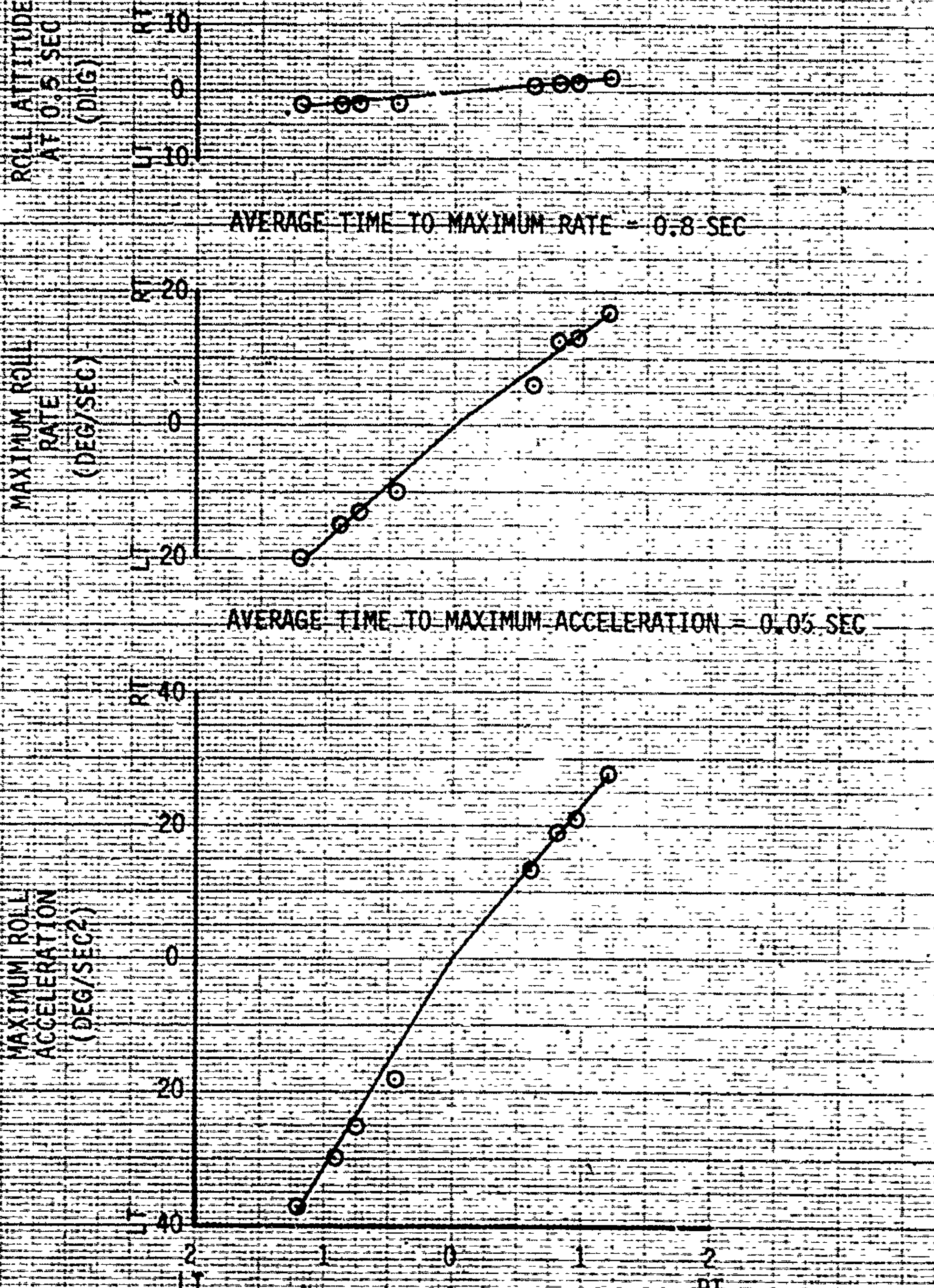


FIGURE 35
LATERAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
30,360	5000	8	329.9	225	121

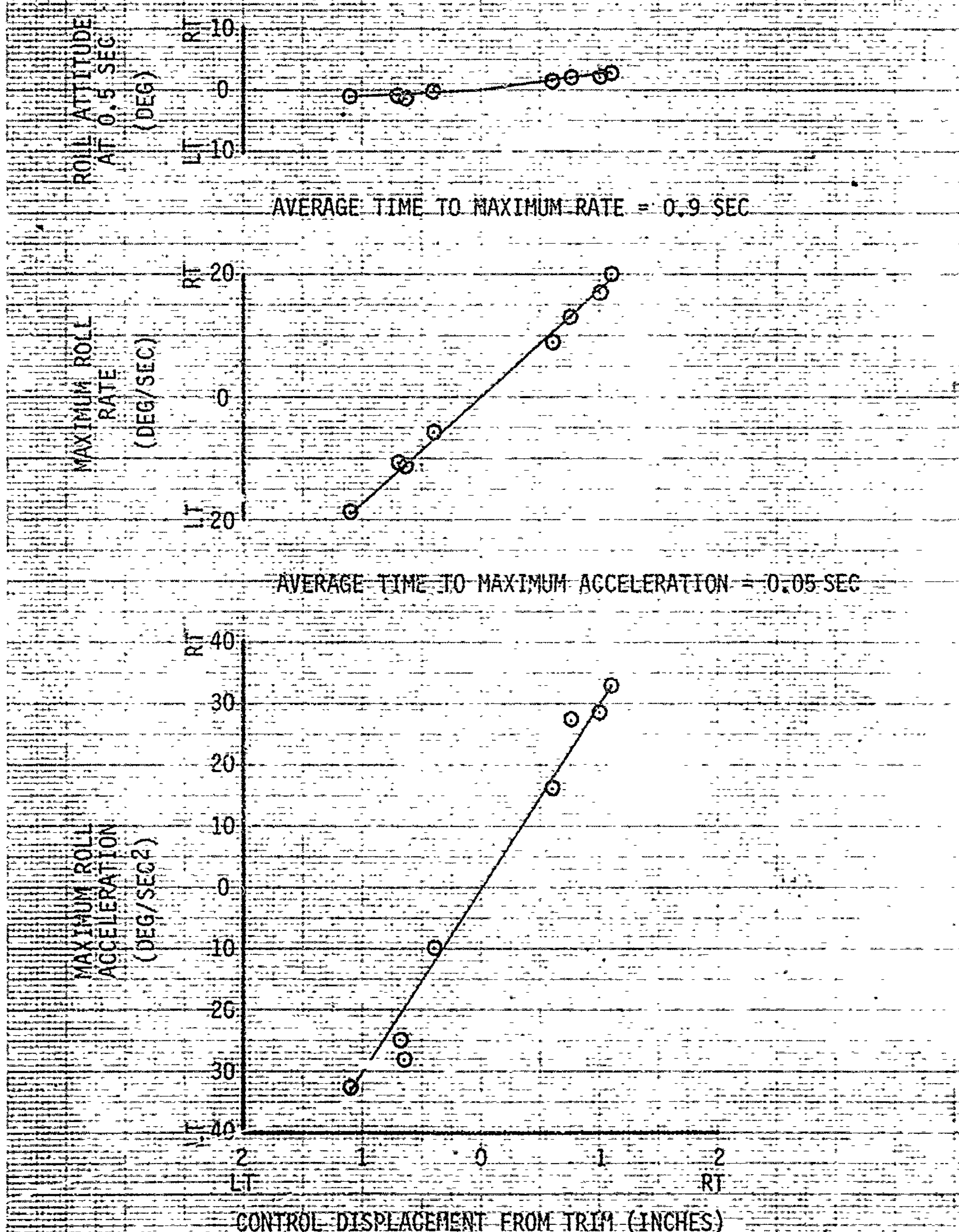


FIGURE 36
LATERAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
HOVER

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)
51280	-700	9	330.4	225

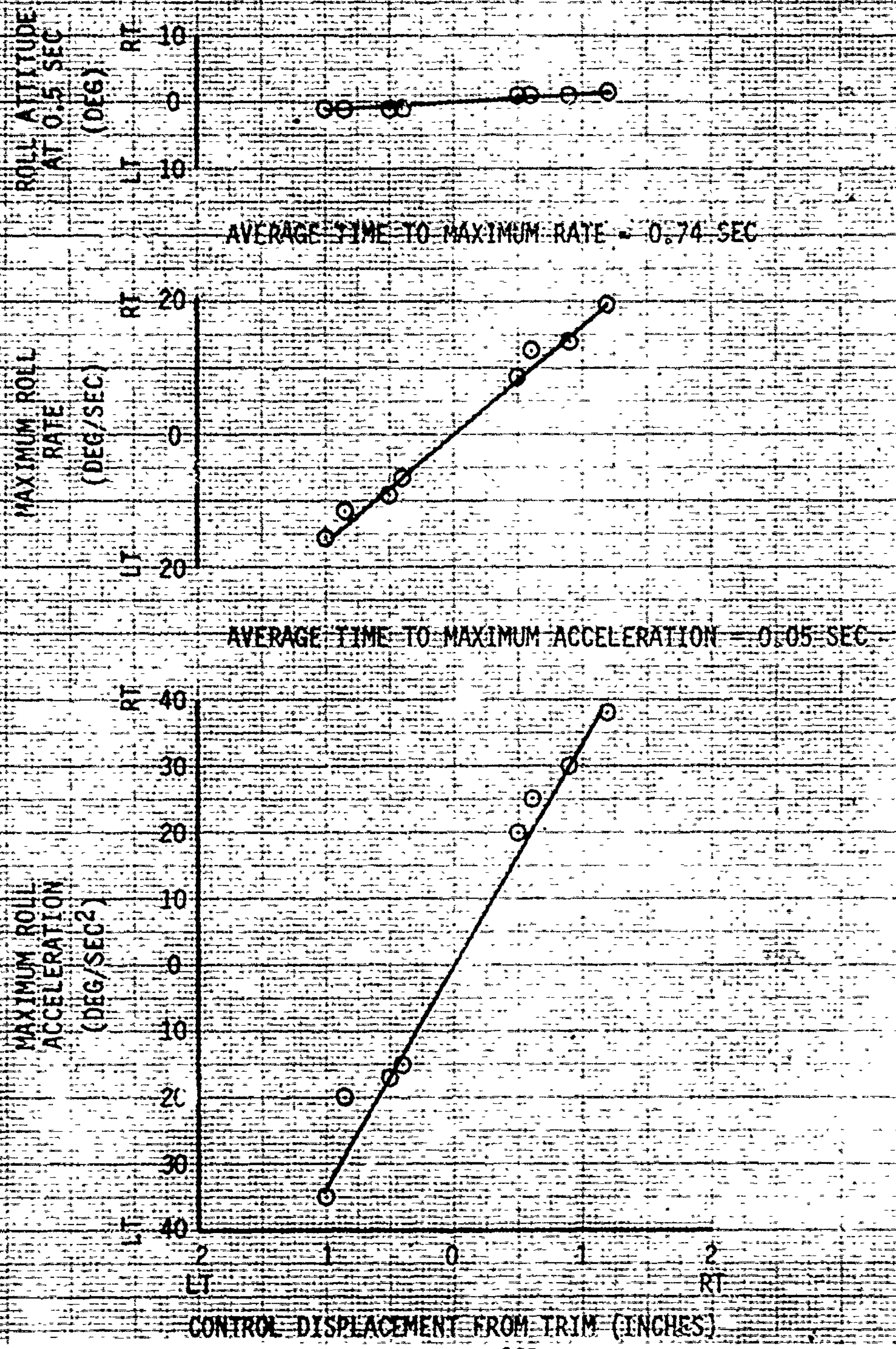


FIGURE 37
LATERAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
49480	5000	7	330.9	225	65

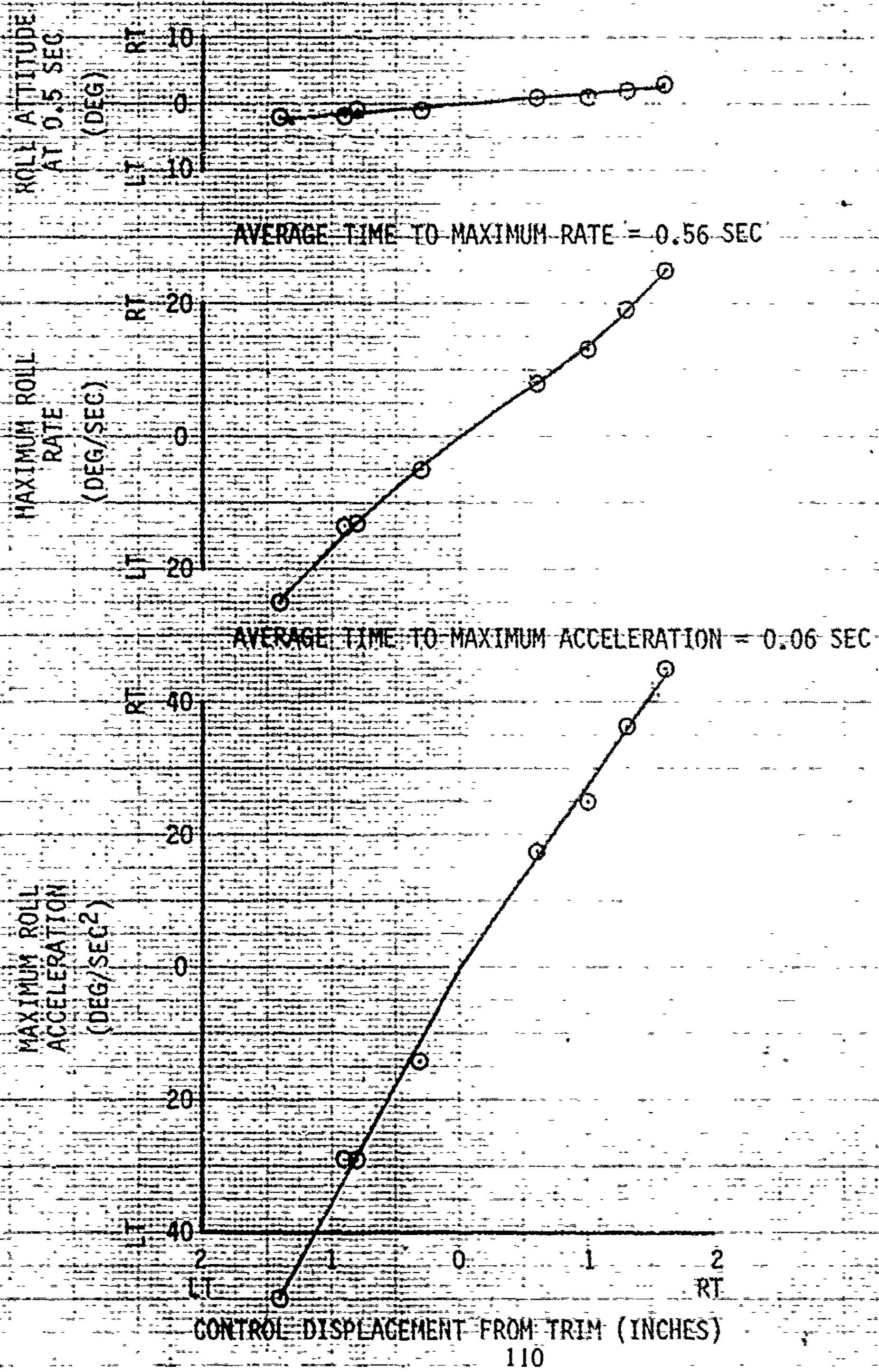


FIGURE 38
LATERAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
50320	5000	-10	330.7	225	121

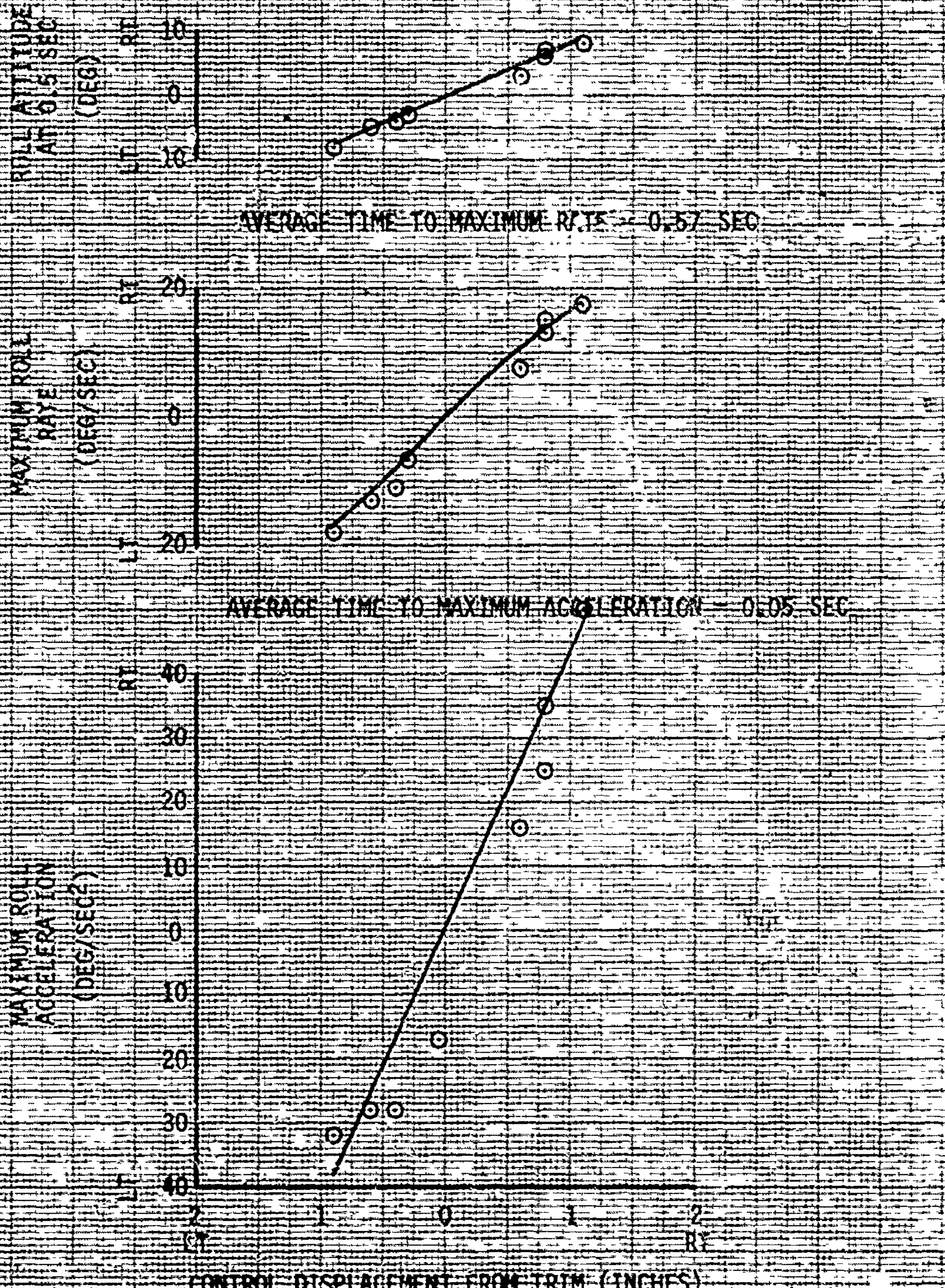


FIGURE 39
LATERAL AIRCRAFT RESPONSE
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
30,360	5000	8	329.9	225	121

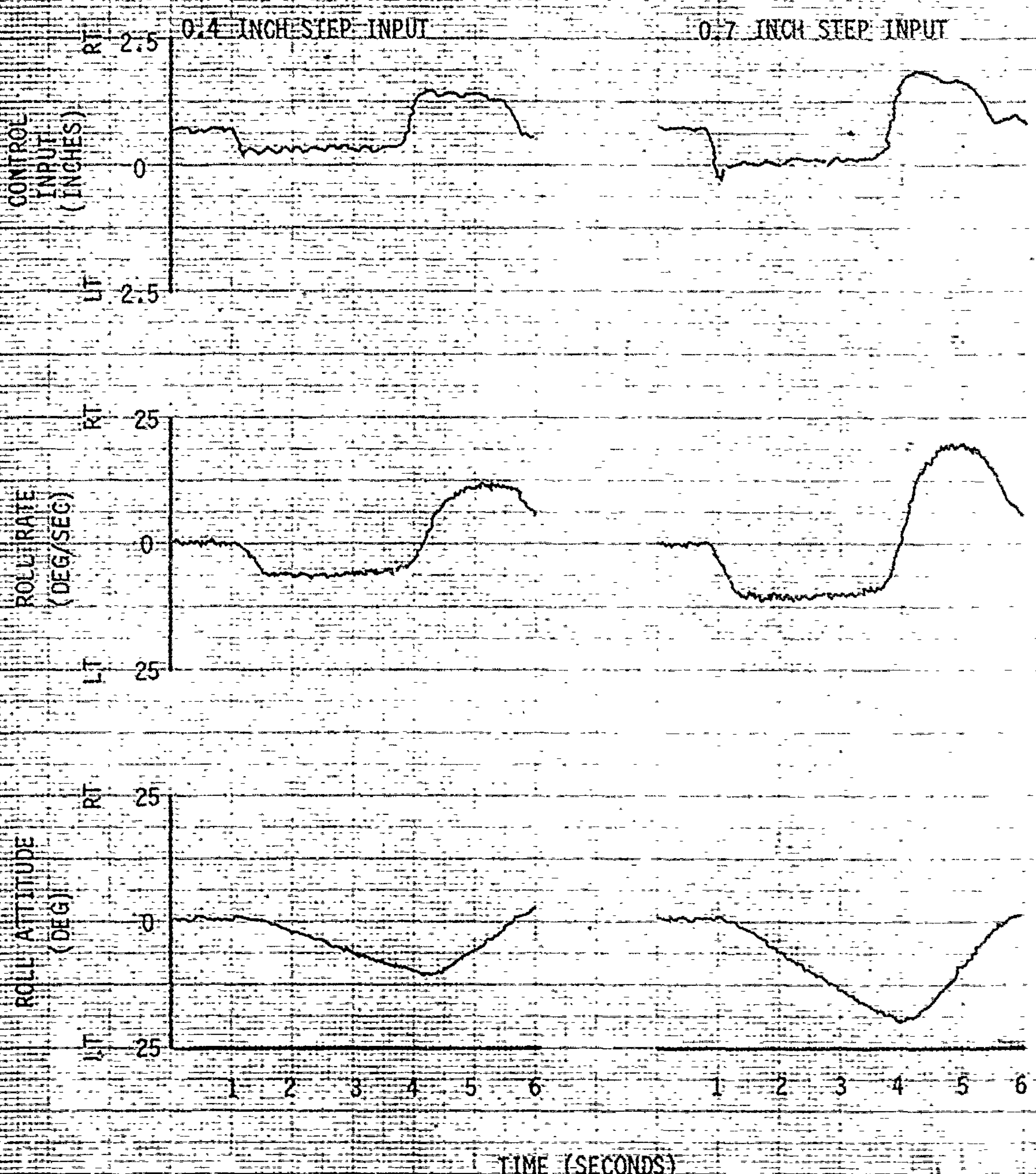


FIGURE 40
DIRECTIONAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
HOVER

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)
32,560	-1000	6	328.9	225

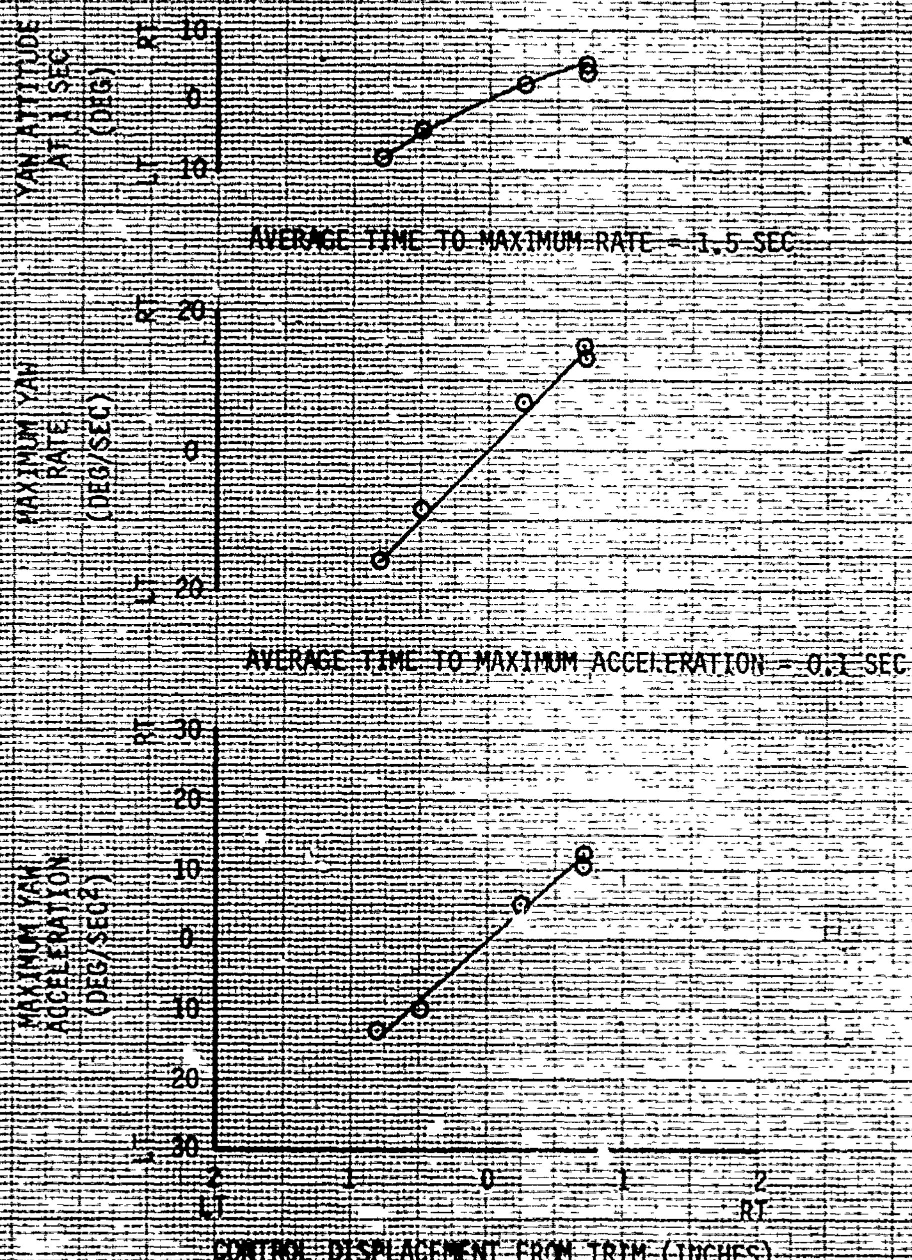


FIGURE 41
DIRECTIONAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
31,900	5000	7	329.2	225	65

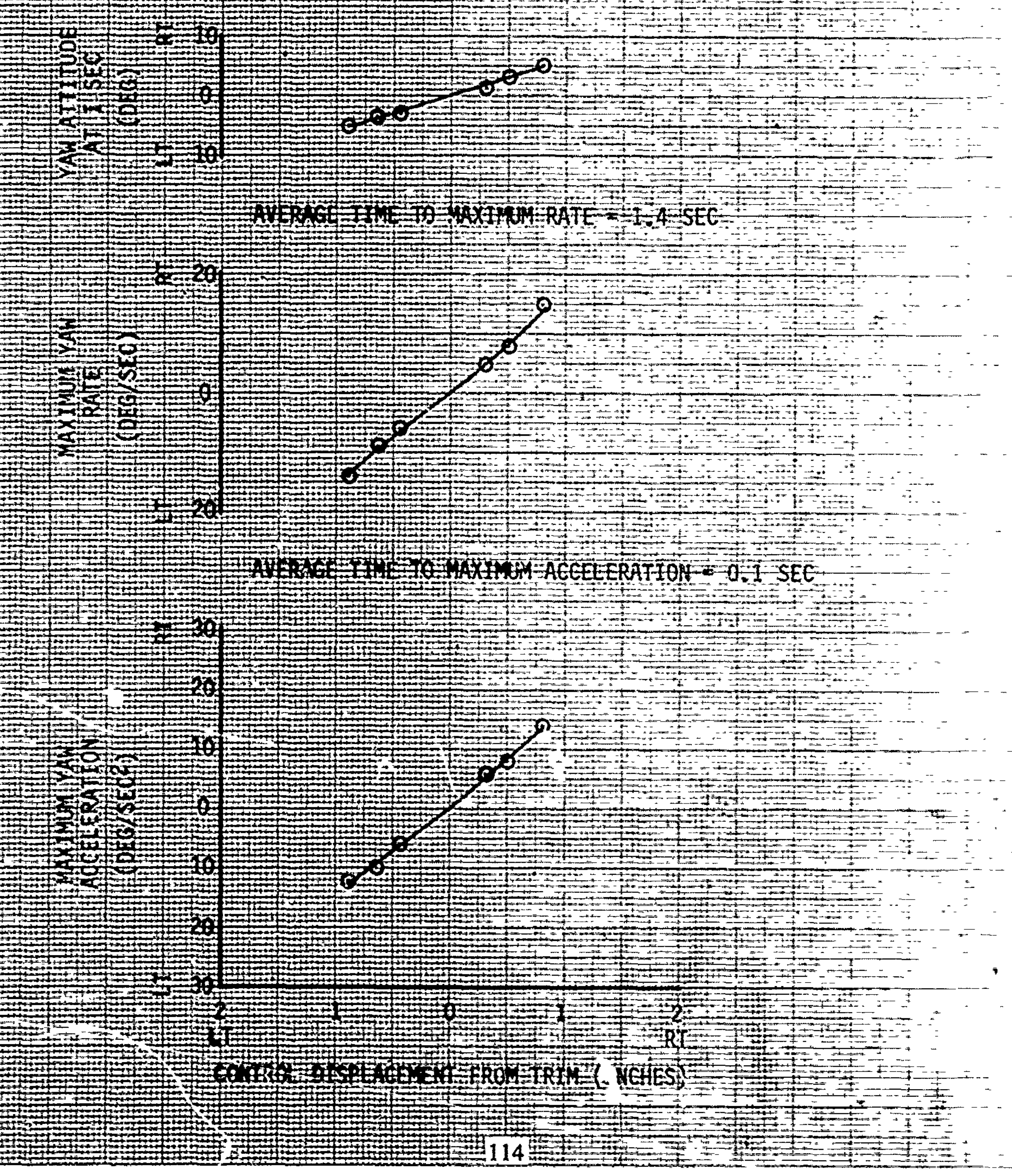


FIGURE 42
DIRECTIONAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
30,360	5000	8	329.9	225	121

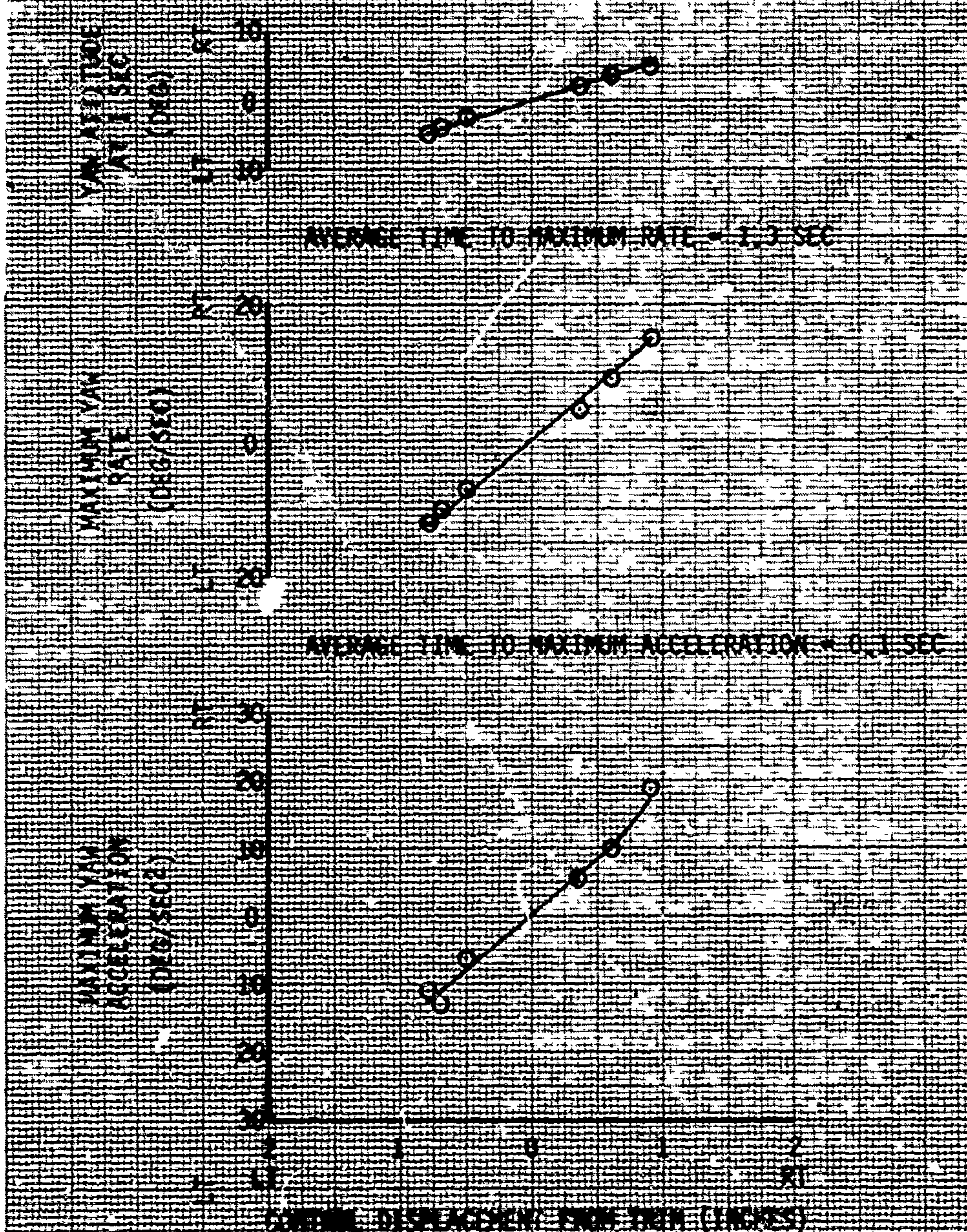


FIGURE 43
DIRECTIONAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
HOVER

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)
51020	-700	9	330.5	225

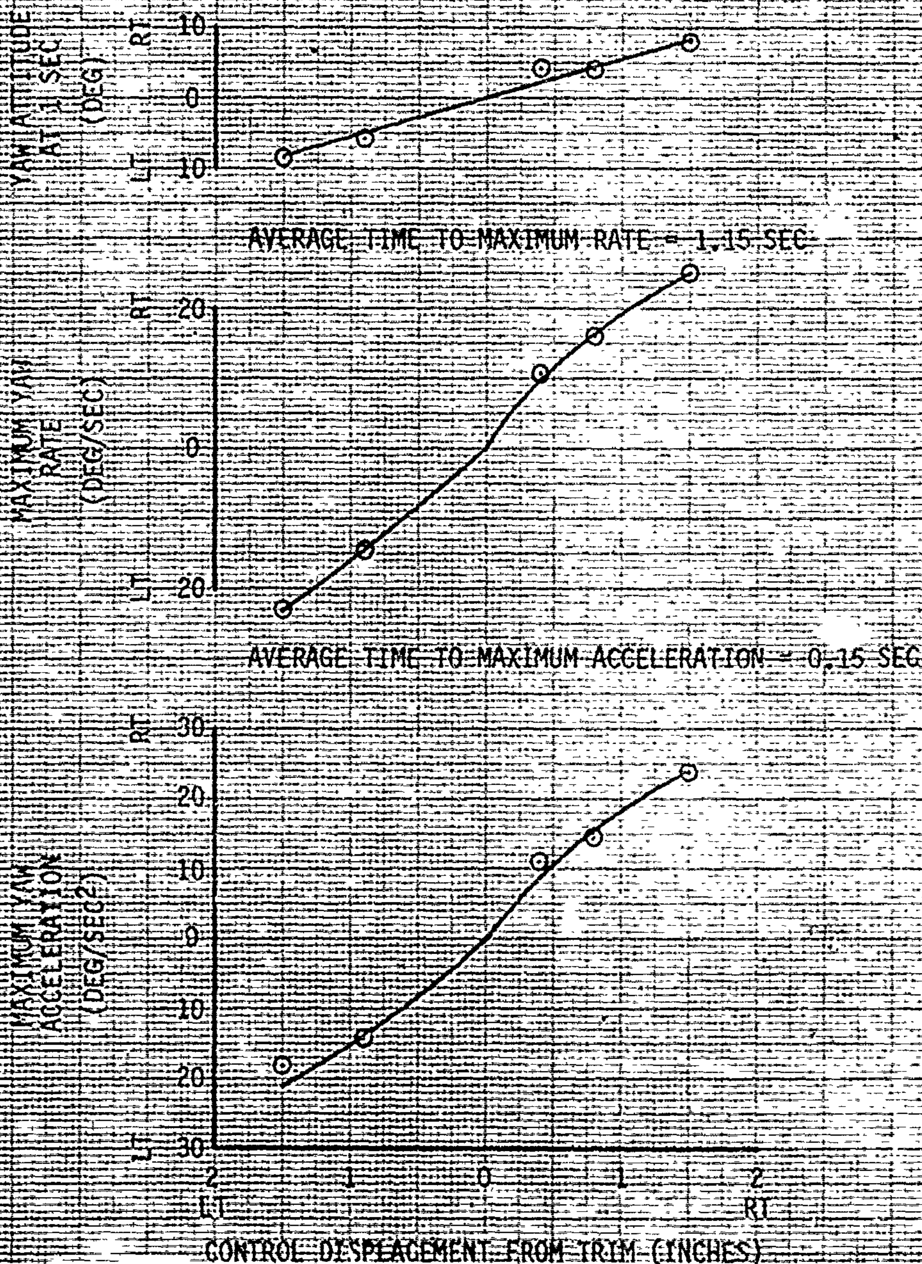


FIGURE 44
DIRECTIONAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
49220	5000	7	331	225	65

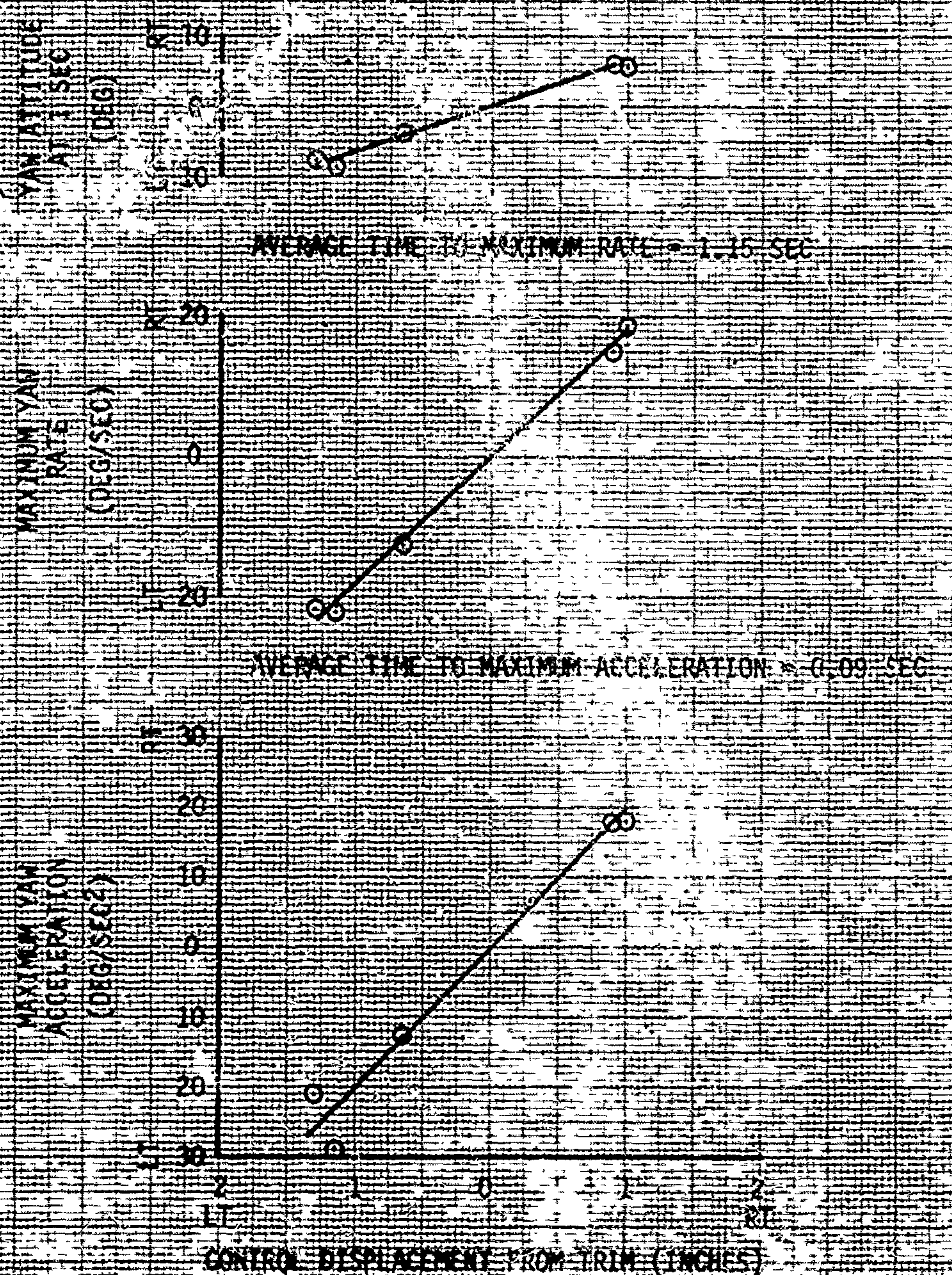


FIGURE 45
DIRECTIONAL CONTROLLABILITY
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN.)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
50020	5000	-10	330.8	225	121

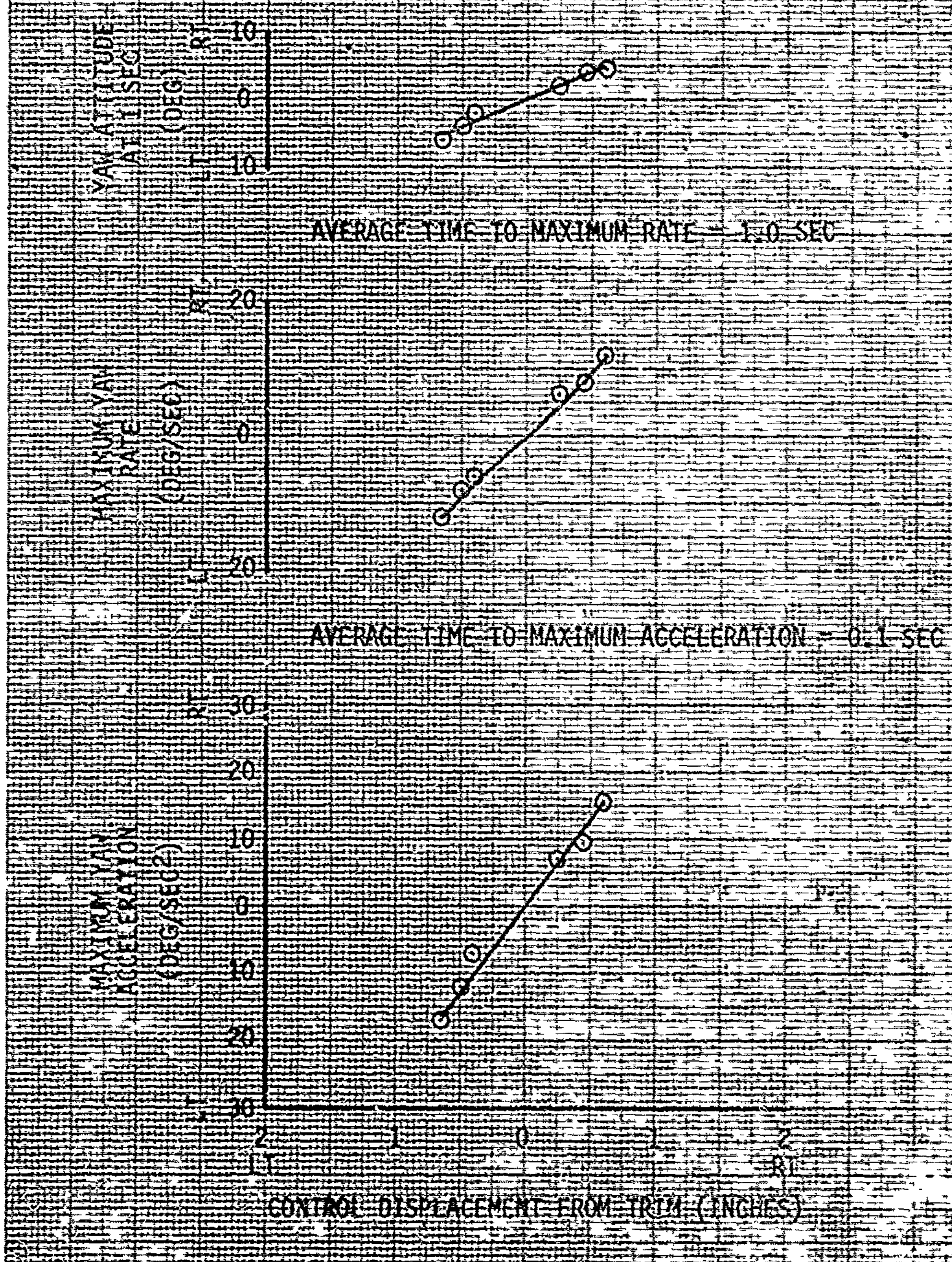


FIGURE 46
DIRECTIONAL AIRCRAFT RESPONSE
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG GROSS WEIGHT (LB)	AVG DENSITY ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG ROTOR SPEED (RPM)	TRIM AIRSPEED (KCAS)
30,360	5000	8	329.9	225	121

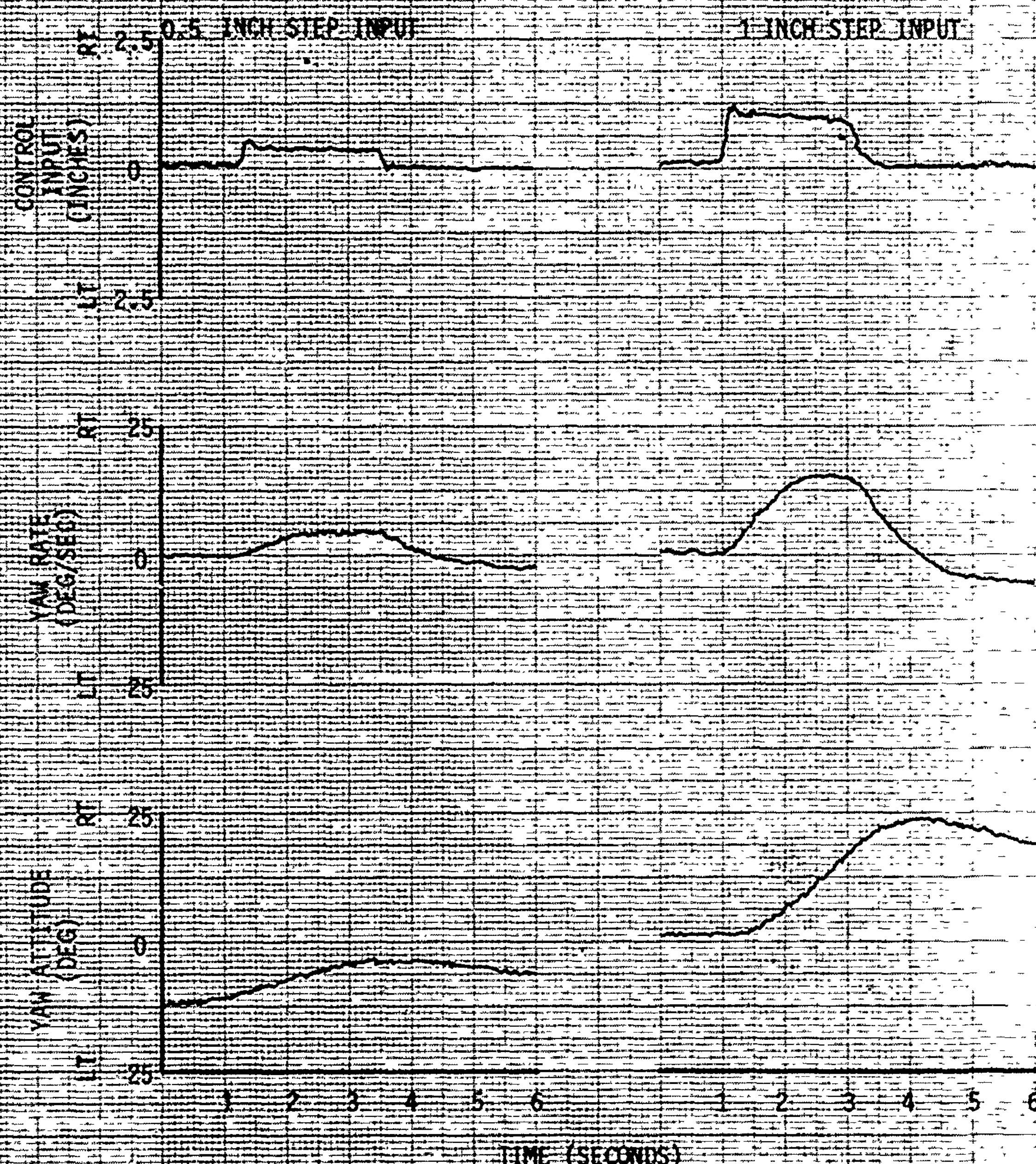


FIGURE 47
VIBRATION CHARACTERISTICS
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG REF GROSS WEIGHT (LB)	AVG PRESS ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG C_T	AVG REF ROTOR SPEED (RPM)
36630	4560	7	327	0.0050	235

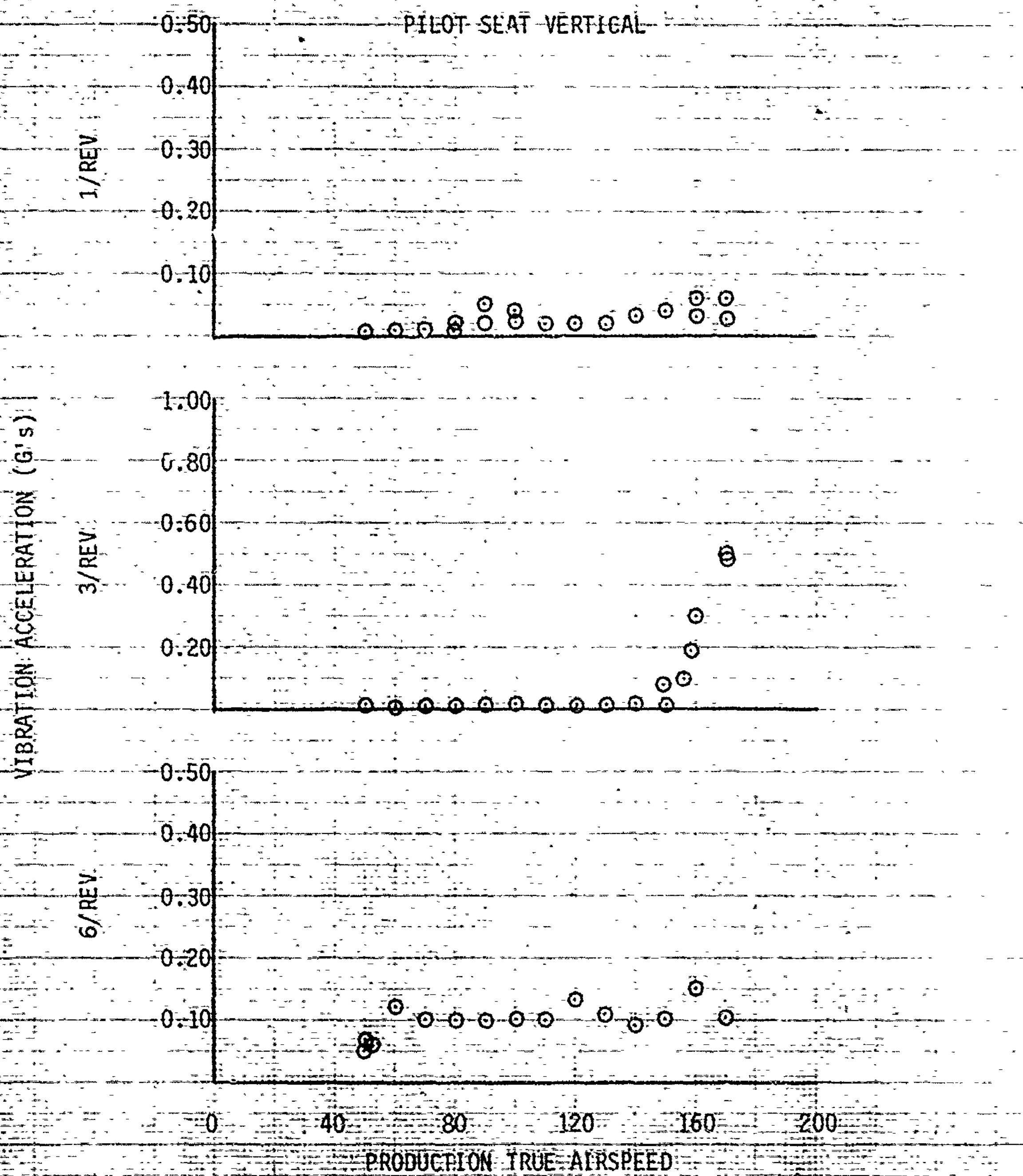


FIGURE 48
VIBRATION CHARACTERISTICS
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG REF GROSS WEIGHT (LB)	AVG PRESS ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG C_T	AVG REF ROTOR SPEED (RPM)
36630	4560	7	327	0.0050	235

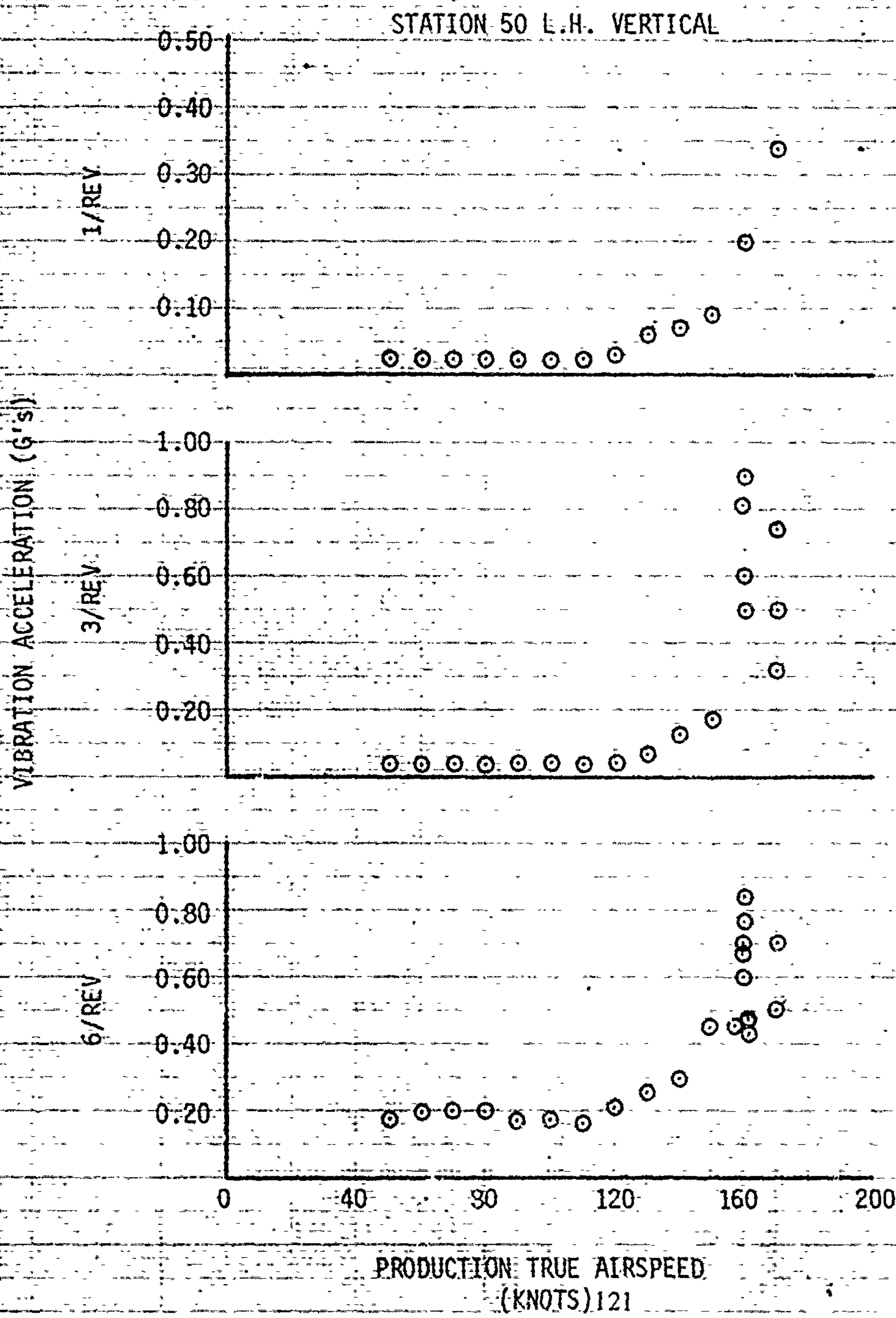


FIGURE 49
VIBRATION CHARACTERISTICS
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG REF GROSS WEIGHT (LB)	AVG PRESS ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG C_T	AVG REF ROTOR SPEED (RPM)
36530	4560	7	327	0.0050	235

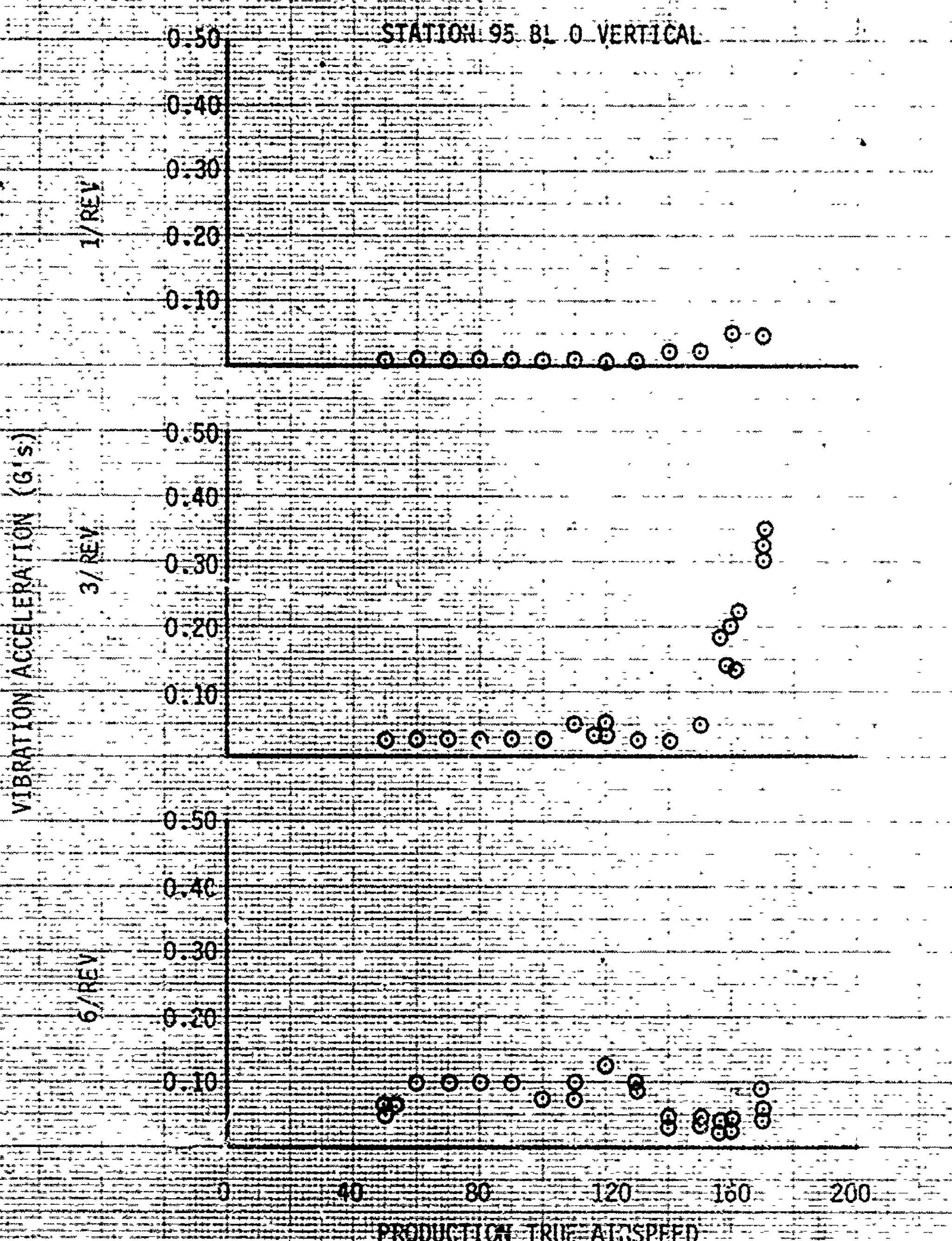


FIGURE 50
VIBRATION CHARACTERISTICS
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG REF GROSS WEIGHT	AVG PRESS ALTITUDE	AVG OAT	AVG CG LOCATION	AVG C_T	AVG REF ROTOR SPEED
(LB)	(FT)	(°C)	(IN)		(RPM)
36630	4560	7	327	0.0050	235

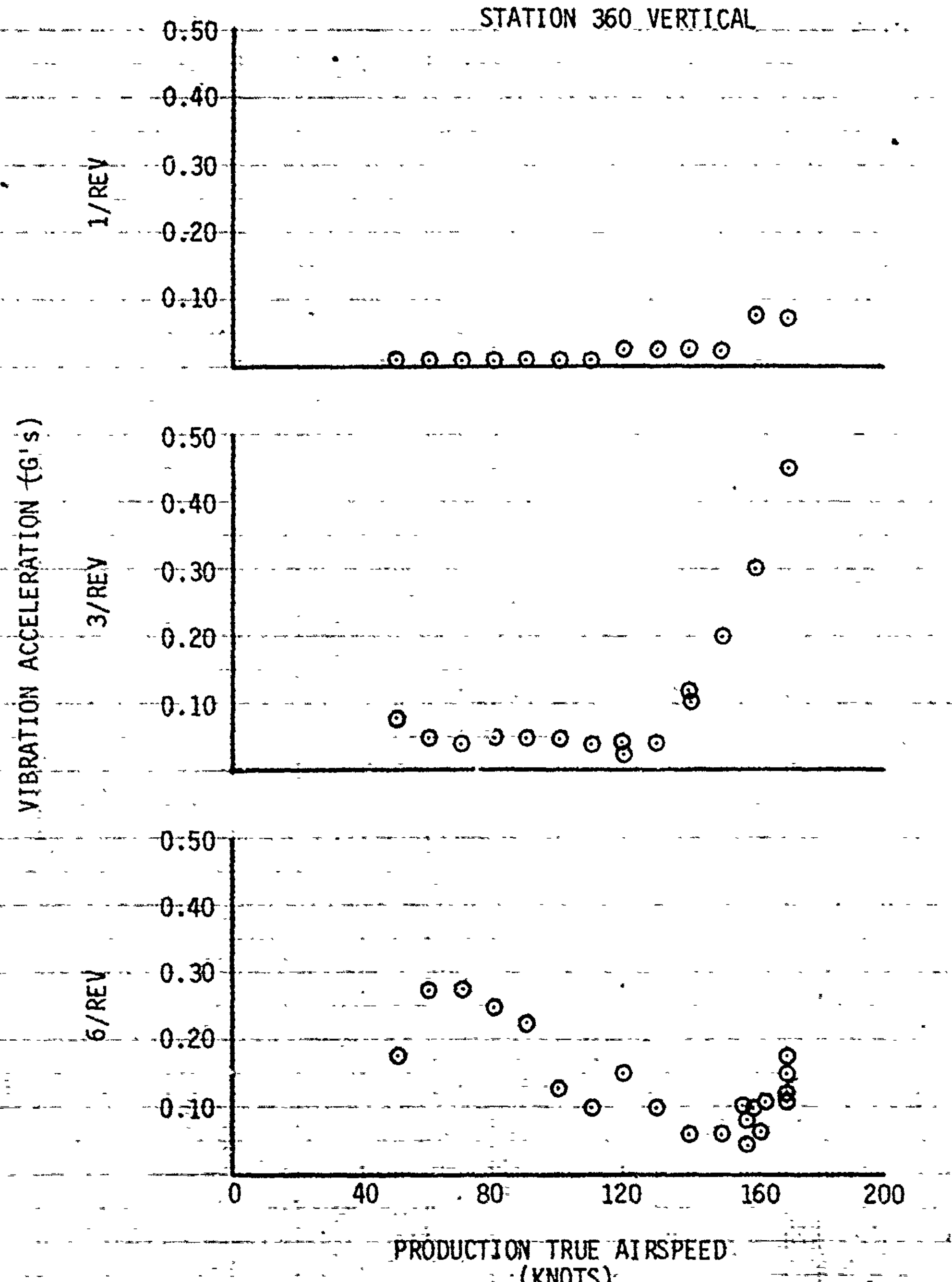


FIGURE 51
VIBRATION CHARACTERISTICS
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG REF GROSS WEIGHT (LB)	AVG PRESS ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG C_T	AVG REF ROTOR SPEED (RPM)
36630	4560	7	327	0.0050	235

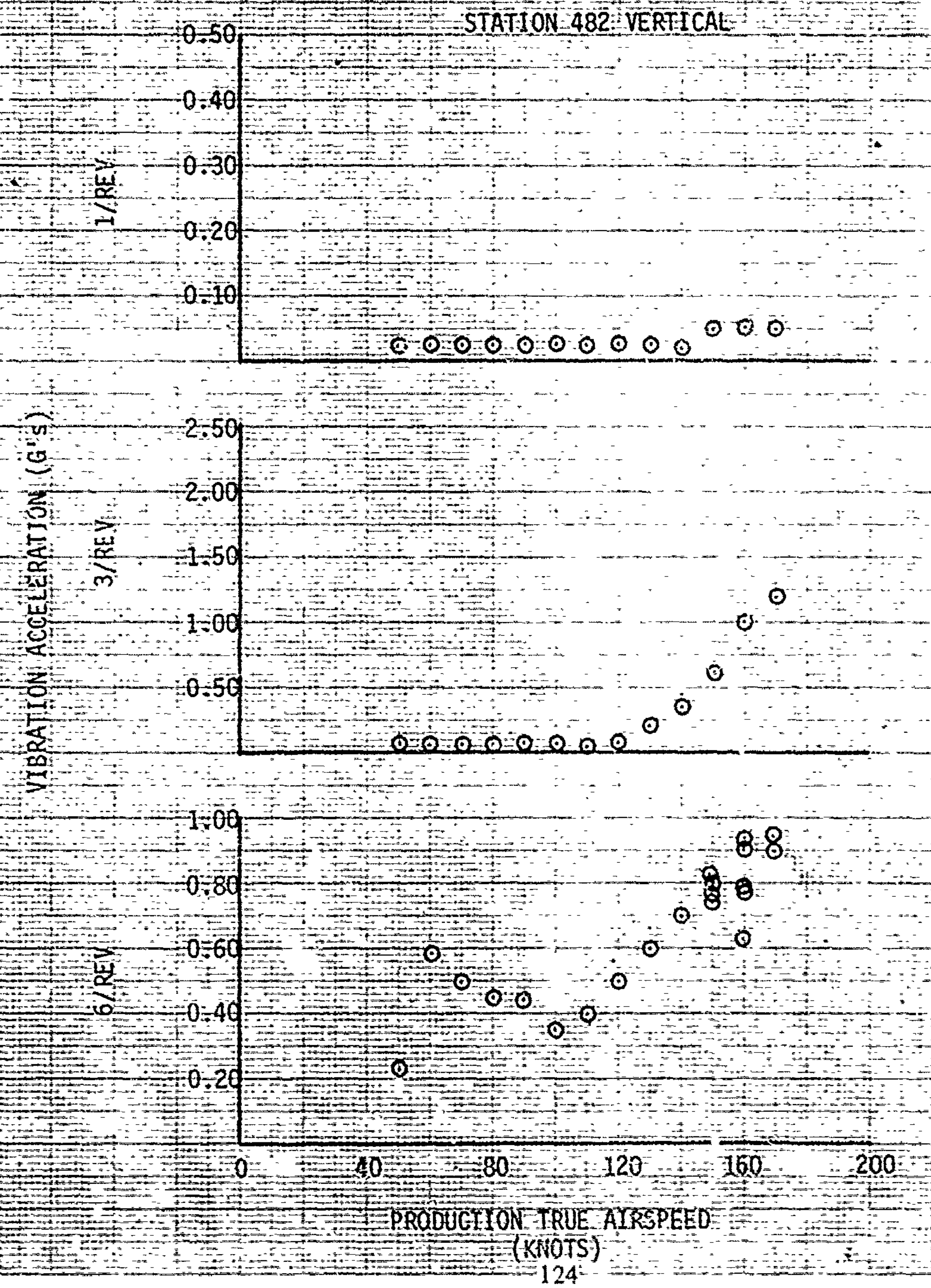


FIGURE 52
VIBRATION CHARACTERISTICS
YCH-47D USA S/N 76-18479
LEVEL FLIGHT

AVG REF GROSS WEIGHT (LB)	AVG PRESS ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG C_T	AVG REF ROTOR SPEED (RPM)
36630	4560	7	327	0.0050	235

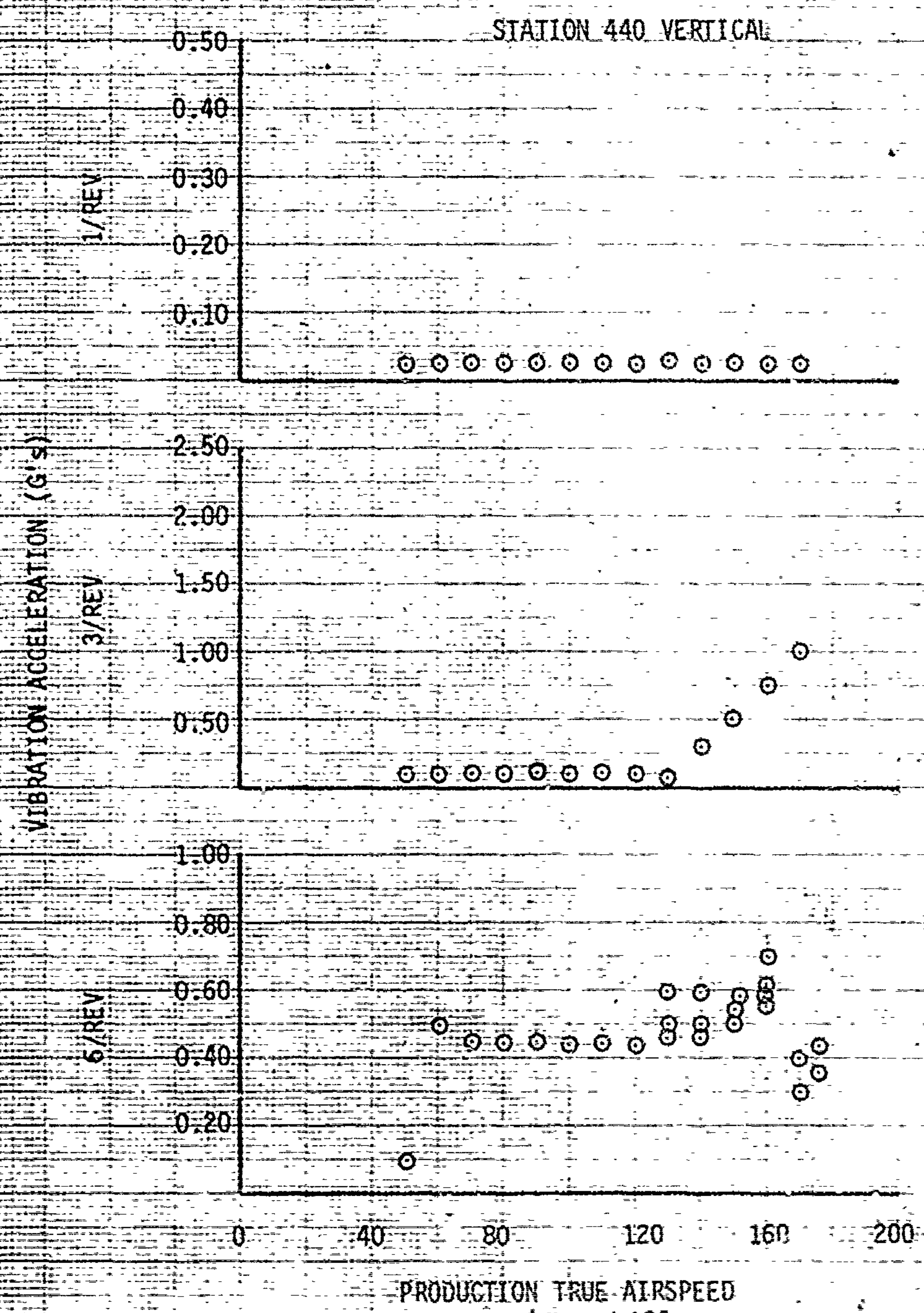


FIGURE 53
VIBRATION CHARACTERISTICS
YCH-47D USA S/N 76-18473
A/S SWEEP
SPECIFICATION VIBRATIONS

AVG GROSS WEIGHT (LB)	AVG PRESS ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG ROTOR SPEED (RPM)
40200	1800	11.5	324	225

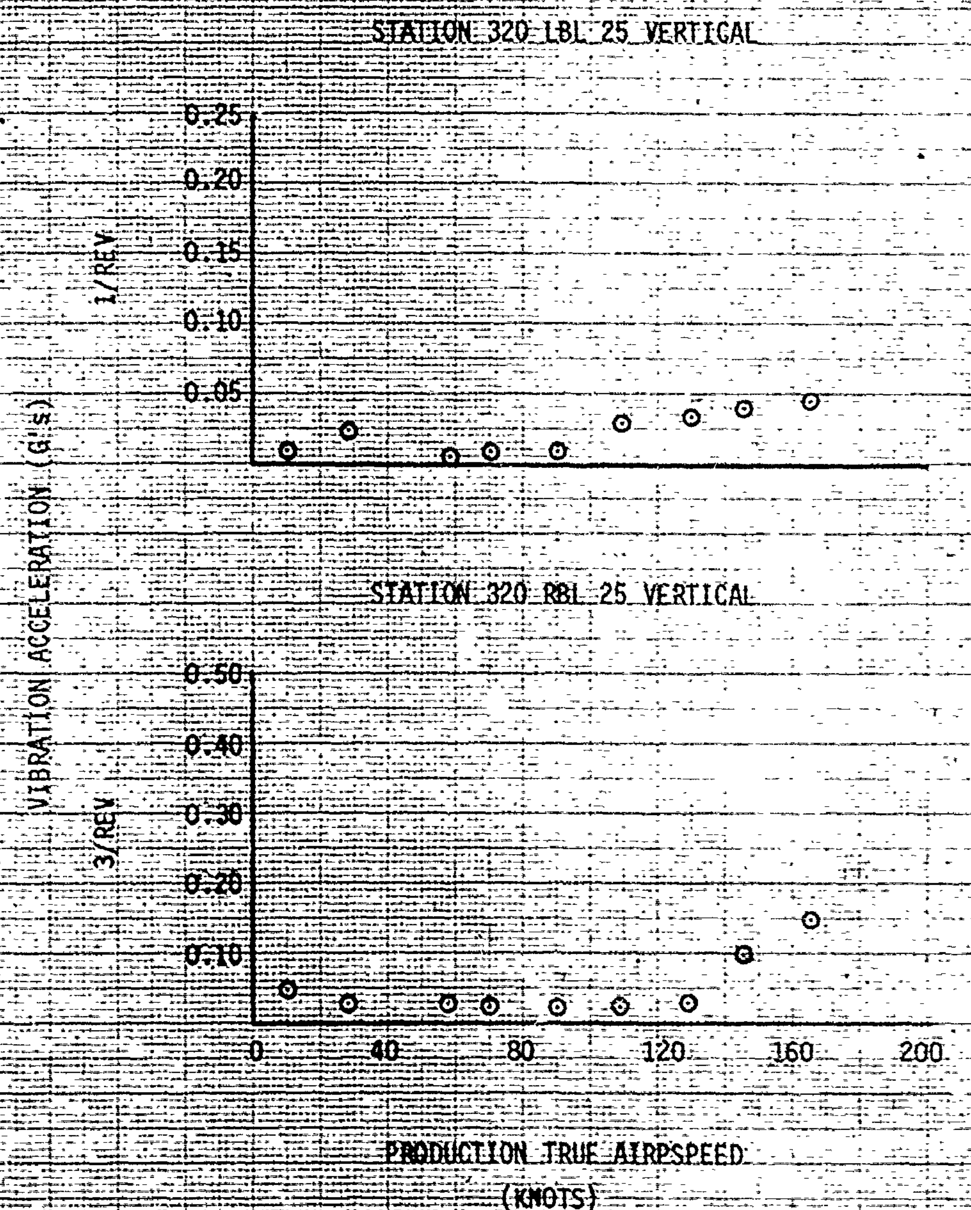
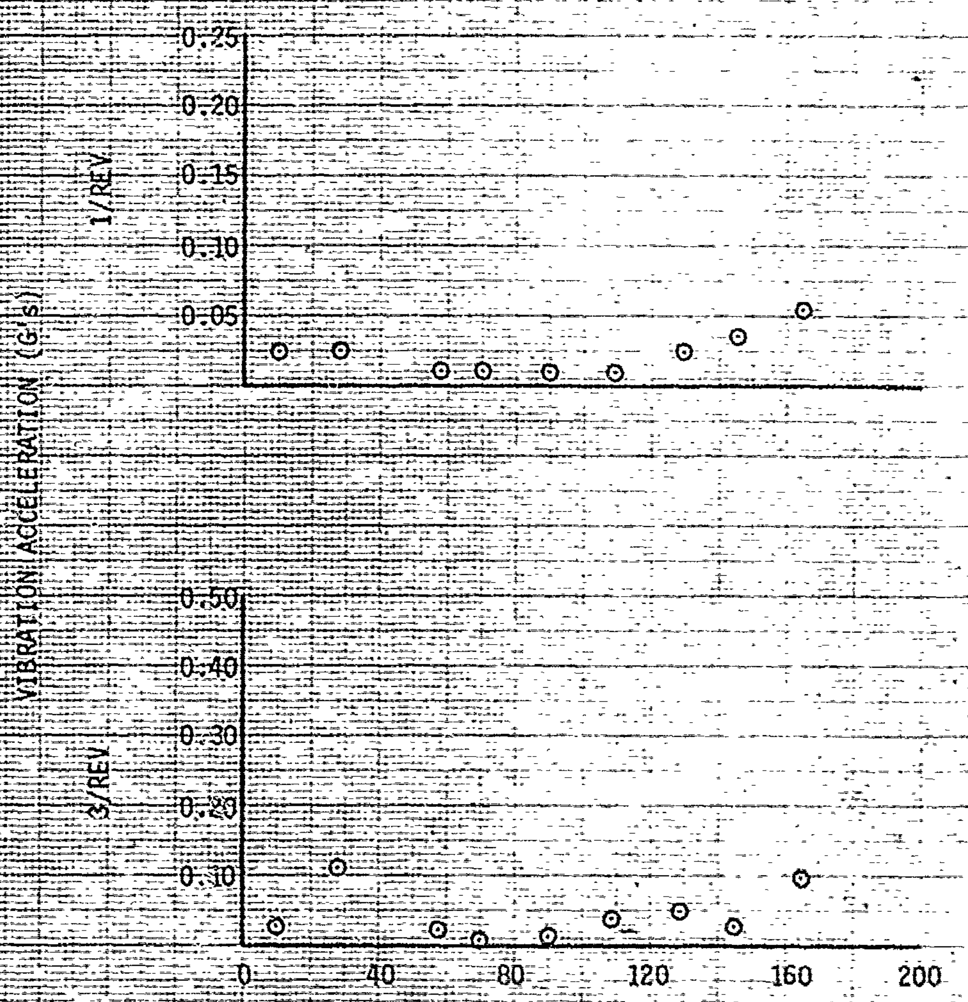


FIGURE 54
VIBRATION CHARACTERISTICS
YCH-47D USA S/N 76-18479
A/S SWEEP
SPECIFICATION VIBRATIONS

AVG GROSS WEIGHT (LB)	AVG PRESS ALTITUDE (FT)	AVG OAT (°C)	AVG CG LOCATION (IN)	AVG ROTOR SPEED (RPM)
40200	1800	11.5	324	225

STATION 95 BL 0 VERTICAL



PRODUCTION TRUE AIRSPEED
(KNOTS)

FIGURE 55

NOISE LEVEL
(COCKPIT AREA)
YCH-47D USA S/N 76-18479

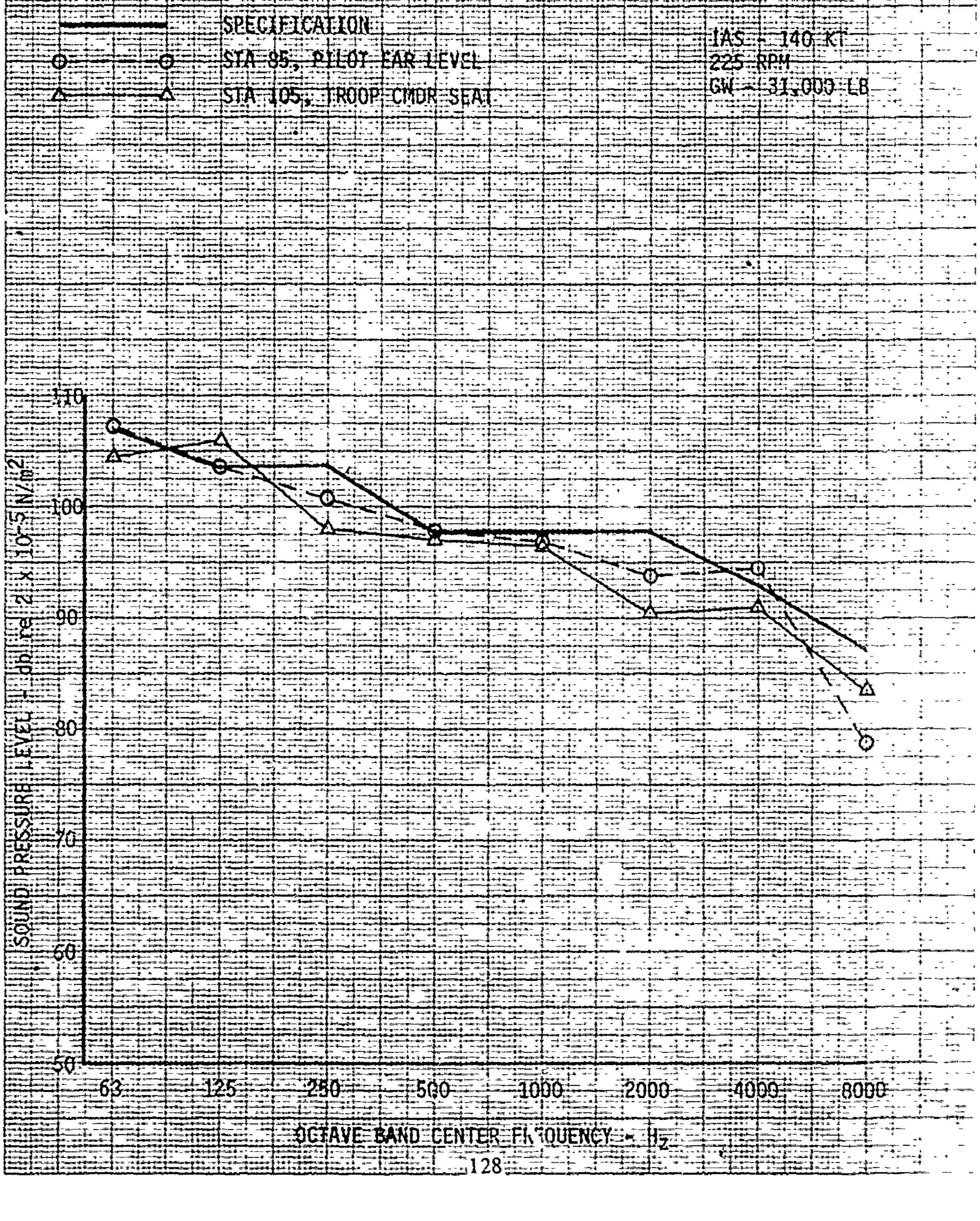


FIGURE 56

NOISE LEVEL
(CABIN AREA)
YCH-47D USA S/N 76-18079

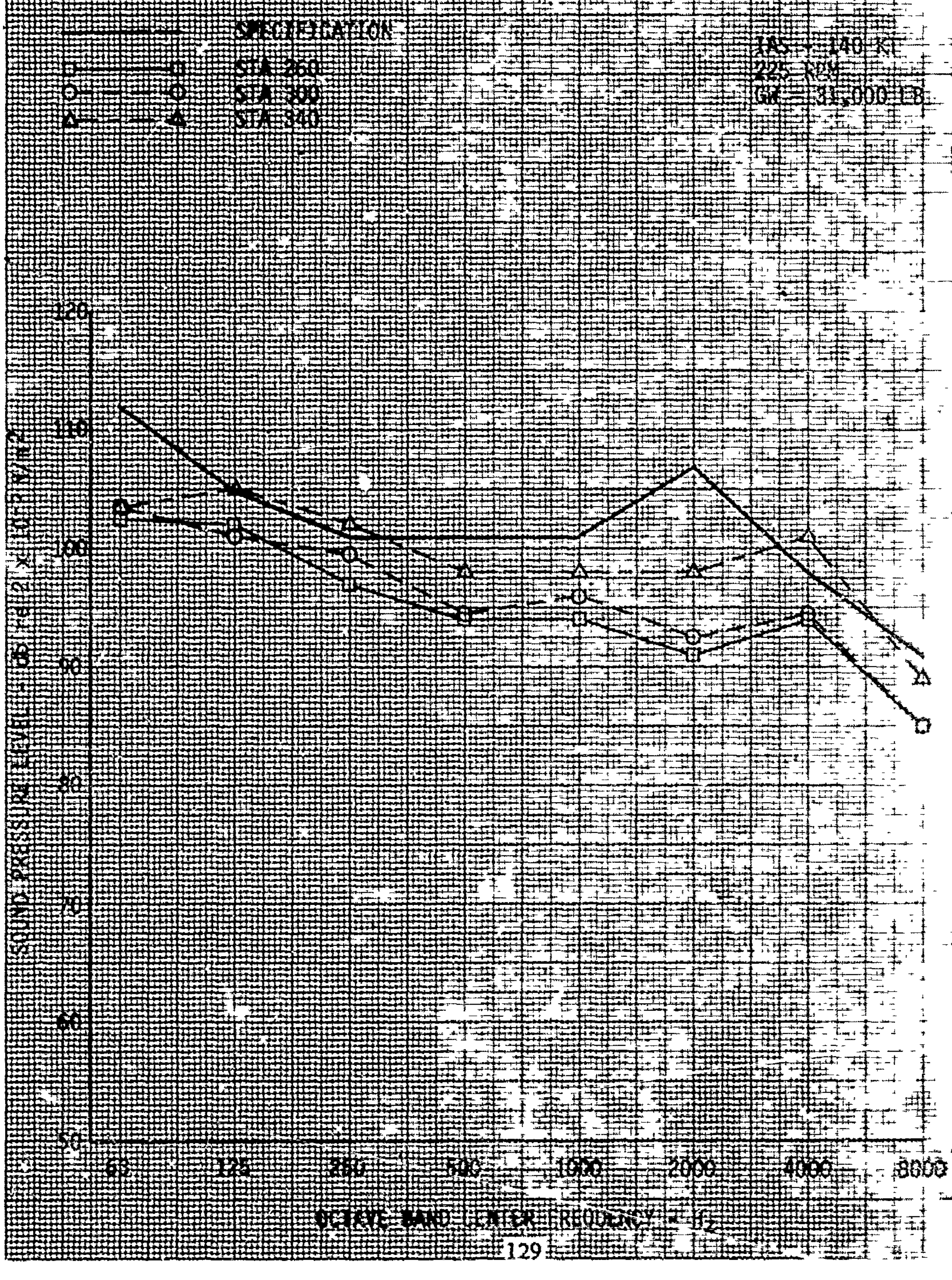


FIGURE 57
NOISE LEVEL
(COCKPIT AREA)
YCH-47D USA S/N 76-18479

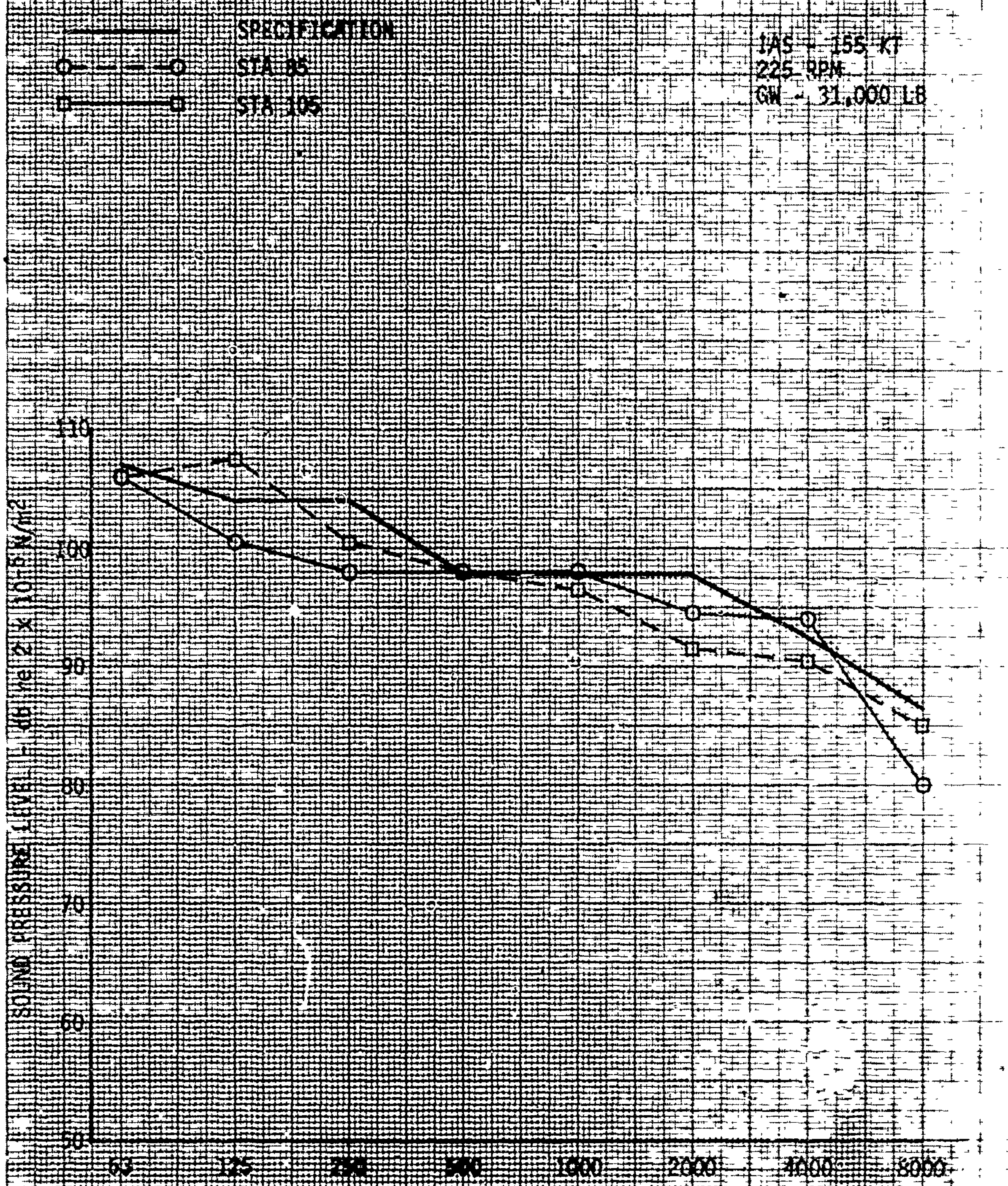


FIGURE 58
NOISE LEVEL
(CABIN AREA)
YCH-47D USA S/N 76-18479

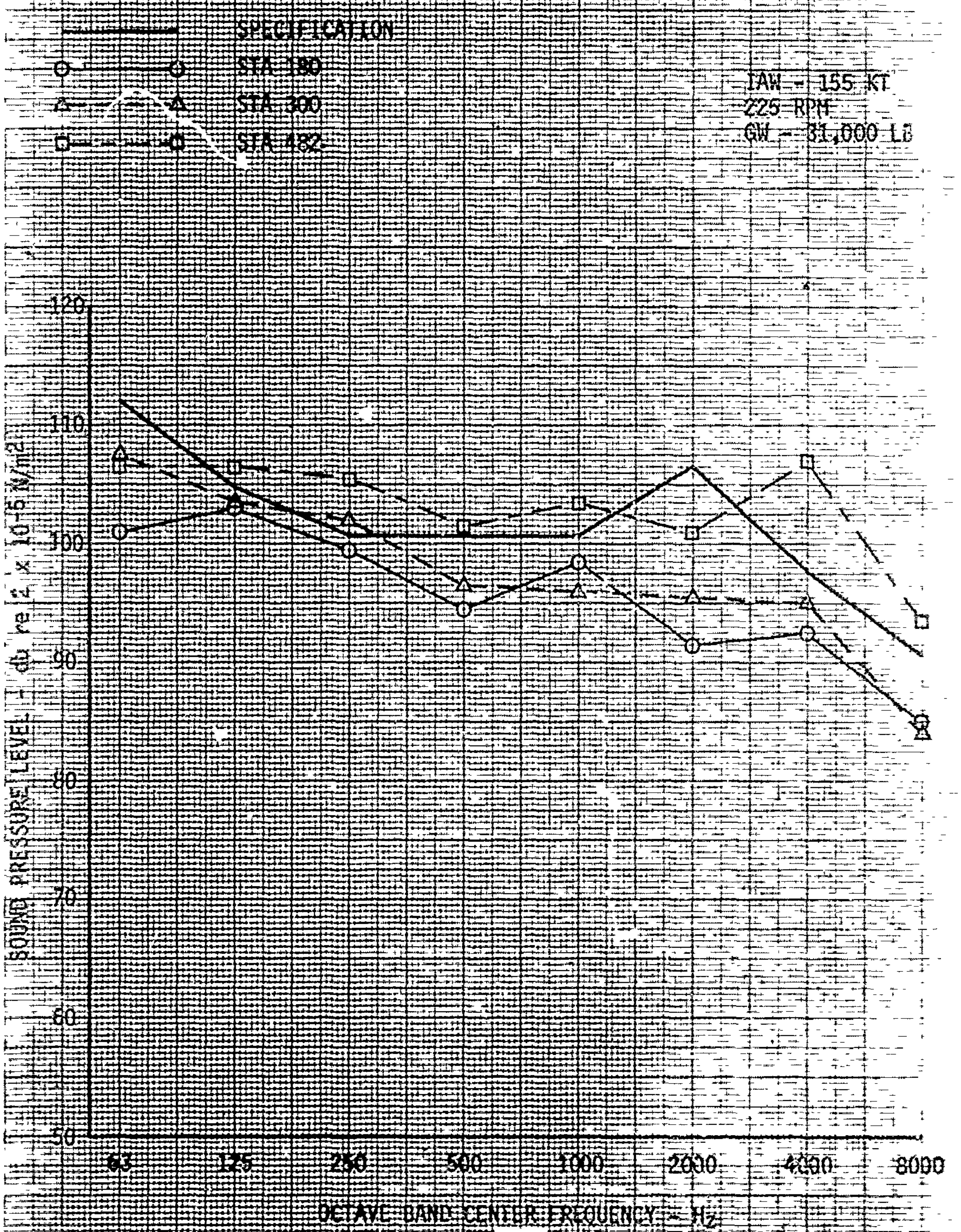
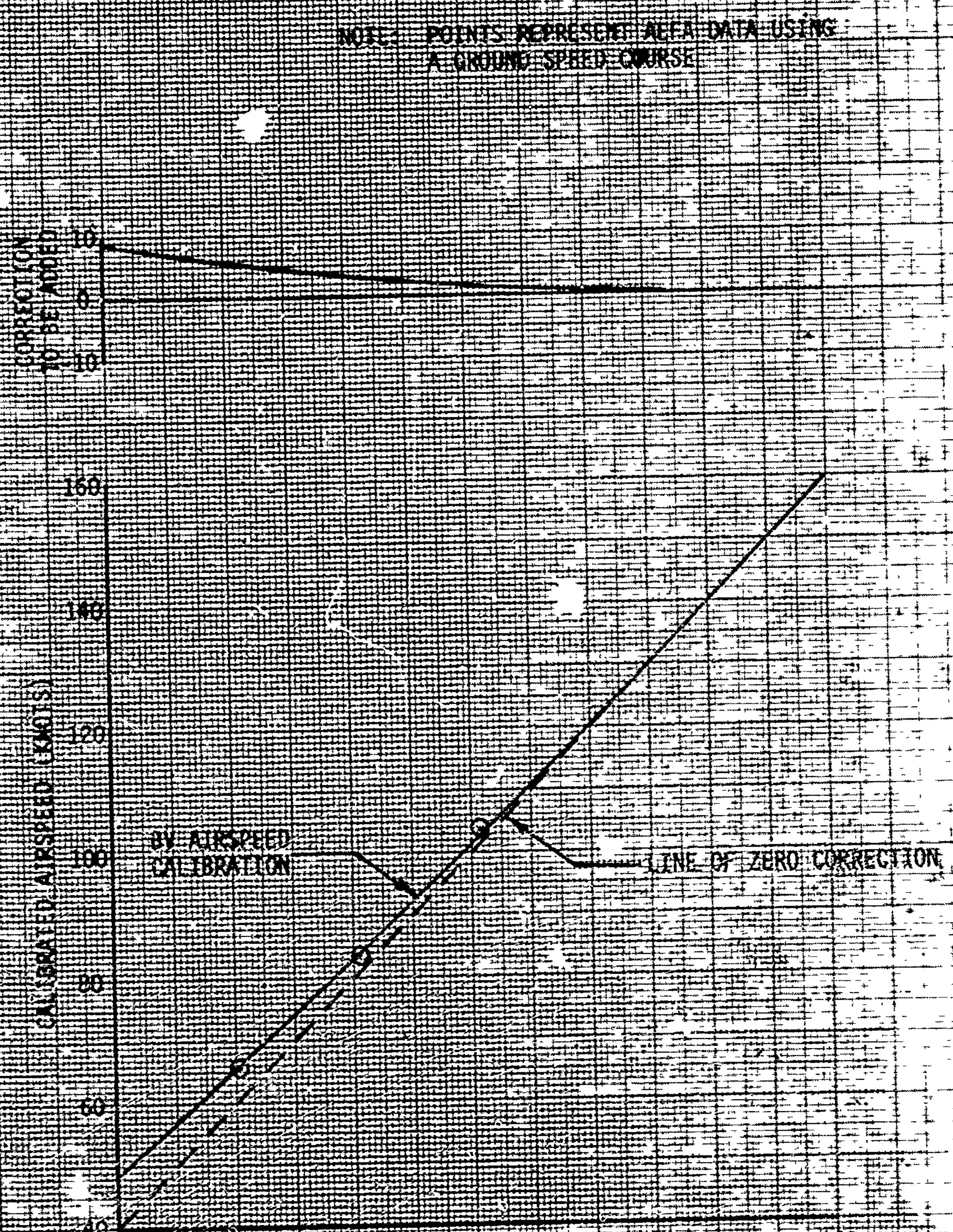


FIGURE 59
AIRSPEED CALIBRATION
YCH-47D USA S/N 76-18479
STANDARD SHIPS SYSTEM
LEVEL FLIGHT



APPENDIX F. EQUIPMENT PERFORMANCE REPORTS

The following EPR's were submitted during the YCH-47D PAE.

EPR NO.	Descriptive Title
79-06-01	Bellcrank Assembly
79-06-02	Seal, Dynamic - Input Shaft
79-06-03	Cap Trailing
79-06-04	Cap Trailing
79-06-05	Rotor Blade, Forward Red
79-06-06	Magnetic Pickup
79-06-07	Ring Assembly - Stationary Component Swashplate
79-06-08	Differential Pressure Indicators
79-06-09	Pump Fail Indicators
79-06-10	Debris Detector Assembly Engine Transmission
79-06-11	Vertical Shaft Chip Detector

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